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SYLLOGISTIC REASONING IN VARIED NARRATIVE FRAMES: ASPECTS OF LOGICO-LINGUISTIC DEVELOPMENT

by

©

DAVID PIPER

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FOR MY PARENTS

ABSTRACT

The study examined the effects of certain contextual linguistic variables on the logical performance of subjects in grades 4, 6, and 12 of selected British Columbia schools. It also explored some of the theoretical problems underlying assessment of the development of logical abilities, in particular, those relating to the distinction between concrete- and formal-operational stages, and to any proposed isomorphism between logical processing and formalisms such as the simple propositional calculus.

The task consisted of twenty-seven syllogistic problems based upon the information contained in three narrative texts, a Fantasy passage, a Realistic passage, and a Contractual passage, versions of which were constructed for each group reading level. The logical problems were themselves varied for argument type (Modus Ponens vs. Modus Tollens), for negation, for conditional statement type (Abstract, Concrete and Inducement), and for the mode of answer required (error-recognition vs. production-recall). These problems were supplemented by three questions designed to elicit subjects' metacognitive awareness of the narrative properties of the texts, and a question examining subjects' understanding of the purpose of the test itself.

Three analyses of variance were performed on the data, one 4-way (Grade x Sex x Logical Question Type x Narrative Passage Type), and two 3-way (Grade x Logical Question Type x Narrative Passage Type), the first taking only perfect answer scores, and the second, all answer scores as input. The data supported the hypotheses that all subjects, in keeping with earlier results, would find Modus Ponens easier than Modus Tollens problems, that they would find error-recognition more difficult than production-recall problems, and negative more difficult than affirmative problems. The main findings were of significant interactions between subject groups and treatment variables, most notably arising from the superior performance of grade 6 subjects over the other two groups on the Fantasy passage, and of grade 12 subjects on the Realistic and Contractual passages. No significant correlations were found between subjects' metacognitive scores and their grade levels.

More detailed analysis of the data revealed complex interactions between contextual and logical variables and it was concluded that a shift of emphasis was necessary away from structuralist approaches to the development of reasoning abilities towards models sensitive to the various discourse 'worlds' entered by subjects when working on logical problem tasks.

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CHAPTER ONE

INTRODUCTION

Piaget's Theory and the Development of Reasoning

To date, the most comprehensive and ambitious attempt to account for the development of logical reasoning abilities in children and adults has clearly been that of Piaget (e.g. Inhelder and Piaget, 1958). Of particular relevance to studies of the development of formal reasoning is Piaget's distinction between concrete- and formal-operational capabilities, a distinction which is founded on the claim that children below the ages of 11 or 12 years, in contrast to adolescents and adults, do not comprehend the propositional logical system as a whole and so are usually unable to generate more than one possible solution to a given problem. The thinking of adolescents and adults, on the other hand, is claimed to be hypothetico-deductive in nature, a type of thinking which Flavell (1963), in a concise interpretation of Inhelder and Piaget (1958), has described in the following way:

> To try to discover the real among the possible implies that one first entertain the possible as a set of hypotheses to be successfully confirmed or infirmed. Hypotheses which the facts infirm can then be discarded; those which the data confirm then go to join the reality sector. (1963, p. 205)

Flavell further describes the central characteristic of the transition from concrete- to formal-operational reasoning as the extension of thought from the bounds of the real to the possible, that is, to a stage in which thought is essentially propositional and its elements are statements about reality rather than reality itself (Ibid. p. 206). In Piaget's theory, the formal description of this integrated system of adolescent and adult thought centres on the logical structures it is held to contain (i.e. the lattice system, comprised of the sixteen combinations of base associations; p.q, ∼p.q, p.∼q, and ∼p.∼q). One clear implication of the theory is that children are incapable of sophisticated conditional reasoning, as this lies at the heart of the propositional calculus and demands both hypothetical and deductive thought.

Criticism of Piaget's Theory

These orthodox Piagetian assumptions have been severely questioned and criticized on a number of grounds. In summarizing current hostility to the theory and, specifically, to the assertion that children younger than the age of formal operations are logically inadequate to deal with propositional reasoning, Falmagne (1975) has identified three underlying reasons for dissatisfaction. The first is the discrepancy between Piaget's data base and the domain of propositional thinking to which the results have been generalized - for example, the generalization from children's behaviour with concrete materials to their linguistic performance. Second, such generalizations can be justified only empirically and yet, at present, there is a severe lack of evidence concerning the development of propositional thinking in a wide variety of situations. The third reason focuses on the definitional problem underlying the whole field of research, namely, the problem of describing precisely what is the logical system children are supposed to acquire and use. As Falmagne puts it:

> ...the fact that adult reasoning in propositional situations is notoriously only in loose correspondence with what the ideal logical model would prescribe, calls for qualifications of what is meant by saying that the individual, from adolescence on, is in the stage of formal operations in contrast to his previous inadequacies in that respect. (p. 2)

Other important objections to the theory concern the concept of stage (discussed, for example, by Ausubel, 1964), the notion of an isomorphism between the propositional calculus and natural reasoning (see below, chapter 2), and Piaget's formulation of propositional logic itself (Ennis, 1978). A further important criticism of Piaget's general scientific approach came as early as 1930 from Hazlitt, who objected both to his apparent insensitivity to everyday observations of children's successful reasoning and to the proposal that if a child could not think logically in one domain, he would be unable to in another (1930, p. 355). Hazlitt's views, supported by experimental evidence of improvement in logical reasoning when language was varied to suit children's needs, were that experience rather than age was the key to thought and that egocentrism was the result of inexperience rather than the source of logical inability. Adults, Hazlitt argued, were just as likely as children to make mistakes with unfamiliar material - or even with familiar material if not previously a matter of concern to them (1930, p. 360).

The Functional Approach to Logico-Linguistic Development

The disparity between the approaches to children's reasoning of Hazlitt and Piaget may be more generally described as a confrontation between functionalism and structuralism. And while Piaget's theory continues to be of great potential heuristic importance for research into logical development, it is the functional approach to children's language and reasoning which is more characteristic of recent theory and research. A central tenet of the approach is that all reasoning takes place in some context, and that whether or not tasks and materials are perceived as sensible within such contexts has important influence on the cognitive processing of propositions. This position has received particularly strong support in the work of Donaldson (1978) who has argued that consideration of children's reasoning out of the contexts in which they normally operate leads not only to observational inaccuracy, but even to unjust and damaging assessment of their capabilities. One example Donaldson gives of the comments made by a six year old while listening to a story well illustrates the presence of secure propositional reasoning even in young children, when situations and materials make sense to them:

> What a lot of things he's taking! He wouldn't have... he's only got two hands and he wouldn't have space for his two hands to carry all these things.
>
> (Premises: (1) Peter has more to carry than two hands can carry.
> (2) Peter has only two hands.
> Conclusion: It is not possible for Peter to carry all that he is represented as carrying. Implied criticism of the story).
>
> (1978, p. 55)

From examples such as this, an important distinction emerges between deductive processing in *concrete* and in *abstract* domains. It is only the latter ability, Donaldson argues, which is apparently lacking in children (Ibid. p. 24).

Current Linguistic Trends

Several recent developments in linguistic theory and techniques provide further impetus to a functional approach to logico-linguistic development. The first, relating to the construction of textual frames in which logical problems may be set, is the turning away from more traditional sententially-based grammatical models (such as those of Chomsky, 1957, 1965) as a foundation for explaining language behaviour, in favour of discourse models which take as their deep structures propositional rather than lexical forms. Parallel to this, following Bartlett's (1932) initiative, there continues to develop a body of research on discourse processes and on the detailed effects of text variables upon inference and memory. Many such variables have been found significant - for example, the hierarchical position of propositions (Meyer, 1975), length and complexity (Kintsch and Keenan, 1973), and surface structural relations (Mandler, 1978). Several techniques have been proposed for the systematic analysis of texts of value in precise experimental measurement (e.g. Kintsch, 1974; Meyer, 1975). While these techniques continue to be refined, the general rationale for studying response to texts is already well established. It has been expressed by Bower (1978) in the following way:

> ...we interpret story book characters and their actions using the same motivational schema we use to understand real-life characters. Therefore, story understanding provides an experimental microcosm or small test tube in which psychologists can isolate and study how people understand the social-behavioural world around them. (p. 12)

A second trend, following important contributions by Austin (1962), Searle (1969, 1975), and Grice (1968, 1975) has been towards the inclusion of pragmatics into the discussion of many aspects of linguistic behaviour. Pragmatic description, unlike syntax or semantics, depends upon accurate modeling of the complex interactions between linguistic form and real-world situations. One study in particular, by Bates (1976), has indicated the significance of pragmatic analysis as a rich source of hypotheses concerning the relations between presupposition, intention and actual language use in children's reasoning.

The third trend is towards a concern with metacognitive factors in processing. The matter of how individual knowledge about various aspects of cognitive functioning affects performance has been approached recently by a number of researchers and from a number of directions. Brown (1975), although concentrating on metamemory (following Flavell, 1971), has provided some essential epistemological and psychological distinctions. Knowing refers to the "dynamic knowledge system", while knowing about knowing "refers to metamemorial processes...or our introspective knowledge of the functioning of our own memory systems" and knowing how to know "refers to the repertoire of strategies and skills we possess for deliberate memorization activities" (p. 105). Brown's major contention was that these three forms of knowledge were to be viewed as distinguishable cognitive systems, the development of which could be systematically observed. Flavell and Wellman (1977) cited several studies in which support for the notion of children's developing awareness of memorial strategies has been found and further suggested that "part of metamemory development...may consist of coming to know when and why we should intentionally store and retrieve information" (p. 10).

The study of metamemory is closely allied with that of metalinguistic awareness. Gleitman, Gleitman and Shipley (1972) reported quite sophisticated awareness of linguistic form in children between the ages of five and eight years when they were asked to detect deviations from grammatical norms. They noticed a dramatic improvement with age, however, in children's ability to reflect upon language, especially in their ability to explain such deviations. More recently, Clark (1978) has reviewed a wide range of evidence of children's abilities to make judgements about linguistic appropriateness, about complexity and form, to correct the linguistic errors both of themselves and of others, to supply appropriate definitions or paraphrases for words and sentences, and even to analyze words and sentences into their component units. Further evidence of metalinguistic awareness has been found in the spontaneous language practice of younger children and in the developing understanding of rhymes, puns and riddles (pp. 28-31). Metacognition, then, is another potentially important source of variation in the development of linguistic reasoning.

Focus of the Study

The recent concentration upon function, context and awareness in linguistic behaviour provides motivation for reassessment of the nature and variability of children's propositional reasoning. The aim of the present study is to provide such reassessment by exploring the effects of certain narrative variables upon the logical processing of grade 4, grade 6, and grade 12 subjects. It is hoped to provide further detailed information on children's and adults' preferences, if any, for textual modes in which logical problems may be embedded and, more generally, to provide further clarification of some of the complex theoretical issues underlying the examination of reasoning ability.

In the following chapter, the particular area of logical interest is defined, together with presentation of a selective review of related research and, finally, a more detailed statement of the underlying rationale.

CHAPTER TWO

EMPIRICAL AND THEORETICAL BACKGROUND

Of central concern in this study is the hypothetical syllogism, a type of syllogism containing at least one premise that is a conditional proposition. Hypothetical syllogisms are to be distinguished from categorical syllogisms, which are essentially quantificational in nature, and upon which most previous research into syllogistic reasoning has been based. The definitions and distinctions relating to these two types have been well documented by Copi (1978) whose terminology will be used throughout the present study.

A hypothetical syllogism may be exemplified as follows:

1. Premise 1:
    If he is a psychologist then he keeps quiet at meetings
    Premise 2:
    He does not keep quiet at meetings

    Conclusion:
    He is not a psychologist.

Conditional propositions such as the initial premise in 1. contain two component propositions - the first, following if, called the antecedent, and the second, following then, called the consequent. There are two sub-types of hypothetical syllogism - those, called mixed hypothetical syllogisms, which contain only one conditional premise followed by a categorical premise (as in example 1.), and those, called pure hypothetical syllogisms, containing two conditional premises. Connected with the first type are the four argument forms central to the propositional calculus and upon which examination of the deductive system has largely been based. Two forms are valid Modus Ponens (henceforth MP) and Modus Tollens (henceforth MT), and two invalid - the Fallacy of Affirming the Consequent (AC) and the Fallacy of Denying the Antecedent (DA) (Copi, 1978, pp. 249-252). These forms are represented symbolically in Appendix A.

In addition to these various kinds of argument, several significantly different types of conditional statement may be included within a syllogism. These types are distinguished by the particular implicational characteristics they embody. In the statement

2. If all statisticians are friendly and Tom is a statistician, then he is friendly

antecedent and consequent are purely logically related. In the following example, however, the consequent follows from the antecedent by definition:

3. If Sally is a wife, she is married.

In

4. If sugar is placed in water, it dissolves,

the consequent follows empirically. The situation is more complex in

> 5. If the Whitecaps lose the championship, I'll never watch television again.

Statements of this latter type seem to be based upon a "decision of the speaker to behave in a certain way under certain circumstances" (Copi, 1978, p. 279). A fifth type is used by Copi to illustrate the relation of material implication. In the statement:

> 6. If Hitler was a military genius then I'm a monkey's uncle

no type of causal, definitional, logical, or even decisional implication exists - it seems merely to deny the truth of the antecedent when the consequent is false (pp. 281-282). The logical status of such statements is reduced to the level of rhetorical assertion by the speaker that some connection obtains between antecedent and consequent.

As Copi indicates, the logical operator expressing material implication ($\supset$), together with its associated truth table is normally used to cover all types of conditional statements. Finally, biconditionality is a term used to describe two statements in a relationship $p \equiv q$, i.e., which are materially equivalent. The truth-tables associated with material implication and material equivalence may be seen contrasted in Appendix A.

As indicated above, most previous research has examined the quantificational reasoning demanded by categorical syllogisms. In addition, a third type of syllogism, the linear syllogism, embodying relational terms such as greater/taller-than, and of the general form:

7. $$\frac{\begin{array}{c} xRy \\ yRz \end{array}}{xRz}$$

has been popular as the source of the three-term series problems of intelligence tests (see Johnson-Laird and Wason, 1977, pp. 75-77). Despite the differences between the various syllogistic types, there is clearly a significant overlap between them, and some commonality in the general demands made on cognitive processing by all types of syllogism. Some researchers, indeed, (see, for example, Roberge, 1970, below) have treated categorical and conditional premise statements as equivalent in meaning ("All A's are B's" ≡ "If it is an A then it is a B"). While specific interest in the propositional calculus is justified both in terms of confronting standard Piagetian theory and in terms of assessing the particular characteristics of conditional reasoning in everyday language (as becomes clear from linguistic analyses of if...then, see below), certain findings concerning the processing of categorical syllogisms are also of significance.

History of Research into Syllogistic Reasoning

The effects upon reasoning of the semantic content of syllogisms have been of experimental interest since the study by Wilkins (1928). Wilkins presented undergraduates with categorical syllogisms varied in content types between familiar (e.g."Robert's boats are sail boats..." etc.), symbolic (e.g."All Z's are Y's..." etc.), unfamiliar (nonsense words or obscure scientific terms), and suggestive (materials which strongly suggested pragmatic conclusions at variance with proper logical conclusions). Subjects worked at eighty syllogisms written in booklets and were instructed to disregard all matters but the pure logical truth of the forms. Some of her significant findings may be summarized as follows. First, although individual differences were considerable, familiar material was in general found easier to process than any of the other content types, unfamiliar material was more difficult than symbolic, and the introduction of suggestion also distracted subjects (pp. 25-27). Second, only poor predictability existed between general ability with syllogisms and a measure of general intelligence (pp. 29-30). Third, items of symbolic and suggestive material types were more highly correlated with intelligence than the other two types (p. 76).

Wilkins' study, in its indication of the strong effects of semantic content, set the stage for many subsequent revisions and amendments. The next step may be identified in the studies by Woodworth and Sells (1935) and Sells (1936) who, in a reappraisal of the Wilkins study, found what they called an atmosphere effect in categorical syllogistic reasoning. Briefly stated, the finding was that subjects would be biased by the second line of the syllogism (i.e., its minor premise) depending on its classical designation as an A, E, I or O statement (see Appendix A), and according to the following scheme:

> A has an all yes atmosphere
> E has an all no atmosphere
> I has a some yes atmosphere
> O has a some no atmosphere
> (1935, p. 453).

Woodworth and Sells further suggested, citing behaviour with illusions as support, that "when the subject does not see the relationships (in syllogisms) clearly, he is influenced by the atmosphere of the premise and is inclined to accept the simple converse of any symbolic proposition " (Ibid.).

Following indication of the atmosphere effect, researchers continued to find yet other sources of bias in syllogistic processing. Subjects were found to accept or reject arguments depending upon whether or not they were satisfied by the conclusions to which the arguments led (Janis and Frick, 1943) and, more generally, to judge logical validity of syllogisms on the basis of emotional prejudice. This latter effect was powerfully demonstrated by Morgan and Morton (1944) who, as a part of their study, constructed thirty problems, half of which contained abstract X,Y,Z, symbols, the other half containing subject matter related to vital issues of the day (e.g. the purported characteristics of Italians, Japanese and Nazis). After some more detailed discussion of the prejudicial content effect of each such syllogism, Morgan and Morton concluded that the factor of personal conviction accounted for 35% of subjects' decisions, the factor of atmosphere 25%, and factors of logic and chance 20% each, when emotive materials were presented. This was compared to the 50% influence of atmosphere and 25% influence each of logic and chance with the ordinary materials (pp. 46-57).

These earlier studies each seemed to emphasize the central point that secure deductive reasoning did not come easily to subjects and was, in any case, prone to significant alogical influences. Questions remained, however, concerning the relative difficulty found between particular syllogistic forms and the effects of different modes of presentation. Moreover, the foundational issue of the propriety of testing human reasoning against formal logical standards had not been fully confronted, even though warnings against "logicism" were well established (e.g., by Woodworth, 1944).

Moore and Anderson (1954), whose central purpose was to establish the propositional calculus and the hypothetical syllogism as a viable basis for the examination and explanation of cognitive higher-order processing, also approached some of the more general problems of constructing logical models of human reasoning. They suggested that "to identify 'laws of logic' with 'laws of thought' or, in general, to confuse the logical aspects of problems and the psychological aspects of problem solving is a mistake not infrequently made" (p. 156).

Some further important findings were by Chapman and Chapman (1959) who extended the simple multiple-choice format used by earlier researchers to include a "can't tell" option. As a result of the subsequent analysis, they suggested that the pattern of subjects' responses was more accurately accounted for by assuming that they actually interpreted propositions as their converses (i.e. biconditionally). Chapman and Chapman further observed that there were many instances when such an interpretation is appropriate as in, for example, a definitional case such as "All right angles are $90^\circ \equiv 90^\circ$ angles are right angles" (p.224).

It was with Hill's (1960) developmental study that some of the wider variables were first explored and in which empirical examination of the relations between logic and reasoning was extended beyond the rather restricted quantificational domain. The following extract represents a new compromise between acceptance of the importance of abstract thinking and recognition of the more functional nature of everyday inference:

> There is a sense in which all logical problems are particular and have a context, i.e., from the standpoint of the person, and...it is influential... But there is also a sense in which we speak of abstraction of form, of generalization of logical principles, of the use of formal rules in abstract settings, where symbols may stand for many different statements or for nothing at all. (1960, pp. 22-23)

Dividing her test instrument among hypothetical, categorical, and other quantificational syllogisms (having universal or existential quantifiers), Hill tested a battery of hypotheses concerning a) the ability of children in grades 1, 2, and 3 to make valid inferences from premises representing hypothetical situations, b) the various levels of difficulty posed by the different logical systems, c) gradual vs. discrete stage development, d) the influence of sex, e) the effect of reinforcement, and f) the distinction between written and oral presentation (pp. 32-35). The test instrument consisted of one hundred items, each containing a two- or three- premise argument. Conclusions were equally divided between positive and negative forms and subjects had to judge them as either correct or incorrect. There were sixty sentential logic items, including both simple forms of the conditional syllogism (MP, MT) and compound forms (containing combinations of MP and MT), together with 40 quantificational items. One subgroup was given verbal reinforcement and another received the materials in written form.

Hill's principal ANOVA yielded only two significant main effects, for age and for logical type, and no significant interactions. From this and further analysis, she was led to conclude that there was no difference between the oral and reading groups or between sexes, nor any significant developmental patterns associated with the various types of logical problem presented but that, overall, children of ages 6 through 8 were highly capable of successful recognition of correct logical conclusions (pp. 62-71). One rather unexpected result emerged from closer analysis of the effect of negation in the materials. Hill found that where negation had been included in one of the premises, as well as in the following conclusion, items became significantly more difficult. Further, by comparing these responses with the simple and complex forms in the study, she was led to suspect that something special was occurring with negation beyond the mere addition of complexity (pp. 66-67). Finally, the high degree of overlap between individual scores, she argued, countered the Piagetian claim of discrete stages in logical development. The overall picture was, rather, of gradual and general growth over the logical categories. The development of sentential and quantificational reasoning appeared to be concurrent (pp. 74-76).

Hill's study represented a considerable broadening of the discussion of syllogistic reasoning. However, there were clearly limitations in her use of forced-choice yes/no answers as a basis for examining children's reasoning. O'Brien and Shapiro (1968), dissatisfied with this inherent limitation, first replicated Hill's procedure and then compared results with those following their own procedure, which included in the one hundred items thirty-three having no necessary conclusion. All items allowed the response "not enough information". The first analysis largely confirmed Hill's findings (except that an additional Scheffé comparison suggested a developmental distinction only between age 6 and ages 7 and 8, rather than between each year), but the second analysis was quite different. In this case, significant age differences were found only for the thirty-three items having no necessary conclusion, and only here, where children effectively had to test their own conclusions, was a clear developmental improvement apparent. Children's overall performance on these open items, however, was uniformly lower than on items in the Hill replication. From these results, O'Brien and Shapiro suggested cautious interpretation of Hill's findings - although children may have appeared good at deductive reasoning within Hill's limited framework, they did not seem to be good at testing their conclusions at these ages (p. 537).

Following the previous two studies, Roberge (1970) indicated some further weaknesses connected with the limited type of reasoning examined and the absence of repeated measures techniques. Exploring three content dimensions, concrete-familiar, abstract, and suggestive, together with six basic logical principles (variations of A, E, I, O, forms with MP, MT, AC and DA arguments) and two logical domains, categorical and conditional, which he treated as translatable, Roberge asked subjects to choose from three possible answers - yes, no, and maybe. Results obtained from two hundred and sixty-three students in grades 4, 6, 8 and 10, revealed that MP was significantly easier than other forms for all grade levels except 8 and 10, that detection of the invalid forms (AC and DA) was more difficult for all subjects, and that a hierarchy of difficulty emerged only at the grade 10 level, in which contraposition (i.e., the valid negative transformation as in "All A's are B's ≡ All non-B's are non-A's") was apparently more difficult to process than MT, and the latter more difficult than pure hypothetical syllogisms (pp. 592-593). In addition, some interesting developmental patterns were observed. Performance on MT and on contraposition actually declined after a peak of attainment at grade 8, whereas understanding of the invalid forms improved and performance on MP reached 95% success in conditional reasoning two years before the same level of attainment in categorical reasoning. In the higher grades, better performance was recorded on the fallacies in categorical than in conditional reasoning (p. 594).

The most extensive analysis of the hypothetical syllogism and its place in reasoning to date has been that of Wason and Johnson-Laird (1972). Three areas of their analysis are of particular interest; the effects of negation, the logical status of if, and the distinction between the processing of abstract and concrete materials.

Following studies by Wason (1959, 1961), Wason and Johnson-Laird suggested negation to be at the centre of quite basic conceptual skills in all known languages. In one experiment to test the effects of negation on processing, they presented university students with a non-linguistic situation, a square divided into quarters with coloured discs in each, and asked them to identify accompanying sentences as confirming or denying the state of affairs represented by these materials. They found an order of difficulty corresponding to the nature of the accompanying statements such that True Affirmatives < False Affirmatives < True Negatives < False Negatives (p. 10). Overall results from this and other similar tests were summarized as follows

> It is evident that negative sentences are harder than affirmative ones to grasp, both in terms of the time taken to understand them and the errors involved in so doing; that this is unaffected by practice over a period of 48 trials; and that negation contributes more to difficulty than falsity. (p. 15)

Wason and Johnson-Laird suggested three possible reasons for the increased processing difficulty accompanying negated sentences. First, subjects tended to convert all negative sentences into affirmatives before finally responding. Second, negative information demanded extra comparison with a positive standard for comprehension and, third, negation demanded an extra grammatical transformation in processing (this latter idea arose from the now-defunct linguistic Derivational Theory of Complexity, reviewed, for example, in Fodor, Bever, and Garrett, 1974, pp. 15-20). These three possibilities, taken together, underlay the strong suggestion that negation generally demanded an extra cognitive operation, whatever the details of that might be.

Turning to the interpretation of _if_, Wason and Johnson-Laird first considered some of the problems of paradox connected with material implication, problems which have also been approached in some detail by linguists (see below). Briefly stated, it appeared that there are many statements in English which did not easily yield to interpretation by way of the standard truth-table. An example might be the sentence

8. If John loved Mary, then he married her.

Here, according to the standard reading, the factual falsity of the antecedent (John did not love Mary) is one way of establishing the truth of the whole - a result clearly in conflict with common sense. The alternative reading of conditional sentences, by way of the truth-table for material equivalence, is equally insufficient. A third possibility is the acceptance of a presuppositional account of conditionals. The central idea here, first proposed by Strawson (1950) was that "many statements in everyday language presuppose some state of affairs and, if this presupposition is unfulfilled, the statement is neither true nor false" (Wason and Johnson-Laird, p. 90). Under this interpretation, conditionals yielded to a "defective truth-table", in which only the top two lines of the standard truth-table were truth-functional, (see Appendix A). Considering the range of possible logical models for conditionality, Wason and Johnson-Laird concluded as follows:

> It is evident that a conditional may possess the logic of material implication, material equivalence, or the 'defective' truth-table. It is not a creature of constant hue, but chameleon-like, takes on the colour of its surroundings: its meaning is determined to some extent by the very propositions it connects.
> (p. 92)

This proposal, however, while initially appealing, has not been accepted without some dissent (see Braine, 1978, below).

The distinction between abstract and concrete materials, Wason and Johnson-Laird argued, may be fundamental to any assessment of deductive reasoning and, indeed, may to some extent have explained the divergence between Piaget's and their own observations of formal-operational capabilities. In what amounts to one further example of functionalist opposition to Piaget's theory, they argued that this divergence, apparent in their observation that adults, in contrast to Piaget's claims for formal-operators, failed to generate all possible hypotheses in given situations, depends on the fact that "formal operations are...only elicited by familiar tasks, and not cognitive skills which can be applied to any problem whatsoever" (p. 190).

This view was well supported by evidence from an experiment by Wason and Shapiro (1971), in which problems were presented variously in concrete-familiar or abstract guise. When subjects in an experimental group were required to test the validity of the rule "Every time I go to Manchester I travel by train" in relation to various contingencies represented on cards (Manchester = p, Train = q, Car = not q), they performed significantly better than a control group working with parallel abstract material. The exprerimental group was asked to confront the problem as if the rule represented an actual journey made by the experimenter. An even simpler explanation of these results than subjects' preference for concrete materials, Wason and Johnson-Laird suggested, might be that the story itself "provides a framework into which the subjects can project themselves by an act of imagination" (p. 191). Taken together with similar findings by Johnson-Laird, Legrenzi and Legrenzi (1972), and in clear alignment with the contextualist approach to reasoning, Wason and Johnson-Laird concluded:

> (T)hese two experiments force on us a radical reconsideration of the role of content in reasoning. The nature of the material would seem to be decisive in terms of whether the subjects exercise rational thought. With 'sensible material', in which there is no conflict between the logical and causal requirements, the task becomes much easier. (p. 193)

Since the Wason and Johnson-Laird study, researchers have continued to concentrate on a variety of issues. The matter of abstract vs. concrete syllogistic material was taken up further by Kodroff and Roberge (1975) who in a developmental study found, first, that concrete presentation facilitated the performance of subjects in each of grades 1, 2, and 3, second, in parallel with Roberge's findings for adolescents, that the difference in difficulty between MP and MT items narrowed with age and, third, that where materials had also been systematically varied for relatedness of content (real-life association between antecedent and consequent proposition nouns in the first premise vs. unrelated nouns), children were not significantly worse at reasoning. Fourth, the large number of responses to the request to explain their conclusions which fell into an arbitrary category suggested, in sympathy with O'Brien and Shapiro's finding, that children's explanations at these ages were consistent with a standard concrete-operational analysis. The important matter of individual differences has been taken up by Keating and Carramazza (1977), whose multivariate analyses suggested linguistic ability to be a dominant factor in syllogistic reasoning and that the non-linguistic skills evident in performance on Raven's Progressive Matrices also played a significant part.

Finally, a developmental study by Kuhn (1977) has concentrated directly on the relationship between conditional reasoning and Piagetian stages, and has specifically examined some aspects of such reasoning in a story framework. Contrary to the argument put forward by Knifong (1974) that children's logical errors resulted from a legacy of pre-operational _transductive_ thinking, it was Kuhn's contention that the explanation is directly tied to the limitations in concrete operational thinking actually described by Piaget, that is, to the inability to combine base associations.

Working from the assumption that a concrete-operational grasp of the relation _all_ _p_ _are_ _q_ is a prerequisite to understanding the relation _if_ _p_ _then_ _q_, Kuhn obtained data using a wide range of materials. In her first study, children in grades 1 to 4 were presented individually with a descriptive text, together with illustrative photographs, at the end of which were located either categorical or hypothetical syllogisms for solution. The text concerned an imaginary city called Tundor and its inhabitants, about whom subjects were interviewed. Using this approach, Kuhn found a much higher incidence of correct syllogistic reasoning than had been found in previous related studies using written materials (e.g., Taplin, Staudenmayer and Taddonio, 1974) or concrete models (e.g., Finkelstein, Smith and Wilson, 1969). She found, moreover, on the basis of correlations between the scores on categorical and conditional problems, a tentative developmental sequence in conditional reasoning. First, children interpret _if p then q_ biconditionally. Second, they recognize that _if p then q_ allows _not p, and q_, sometimes generalizing the response "maybe" to syllogisms with logical conclusions. Third, they understand that _q's_ may be either _p_ or _not p_, which step marks "full acquisition of the classical logical interpretation of _if p, q_" (pp. 347-348). From further replication of the Taplin et al. experiment using exclusively written materials but in which the number of test items was much reduced, Kuhn was able to establish that the increased observation of conditional reasoning in her first study was due to the mode of presentation. She concluded that "the real-life meaning of the propositions was evidently necessary...to enable a child to recognize the possibility of _not p_ in conjunction with _q_" (p. 349).

In a final study, Kuhn specifically took up the claim made by Inhelder and Piaget (1958) that the onset of conditional reasoning came only with the capacity both to isolate and combine relations within the complete lattice system. Children in grades 2, 4, 6 and 8 were presented with four tests administered in random order. The first was centred on a narrative passage and tested children's ability to isolate variables. Given four written descriptions of empirical observations, they had to select from a group of three possibilities the only variable related to a given outcome and, further, to justify their conclusions. The third was a written test of sixteen standard syllogisms (MP, MT, DA and AC forms, eight with abstract and eight with meaningful content items) and the fourth, the vocabulary sub-test of the Wechsler Intelligence Scale for Children (p. 351). Kuhn's main findings from these data were that children younger than grade 6 age demonstrated little successful conditional reasoning or ability to isolate variables. Correct conditional reasoning, she argued, was dependent upon ability to isolate variables but was not in evidence before grade 8. Scores on the first test were found not to correlate with scores on the third (standard syllogisms) and the vocabulary measure correlated highly only with the standard syllogism test scores at grade 6 level. All of Kuhn's results apparently supported the notion that children's conditional reasoning, when it was observed under the optimal circumstances provided by way of text-based material (test 1), was dependent upon formal-operational capabilities as defined by Inhelder and Piaget. Standard syllogisms, however, appeared to demand only a concrete-operational level and might be influenced by verbal ability (p. 352).

Linguistic Analysis of Conditional Expressions

Reference has been made in the previous section to the insufficiency of the standard truth-table for material implication as a model of normal language use. A number of more purely linguistic studies have emphasized this point and cast light on the truly varied and complex nature of the conditional system. One such study was that by Geis and Zwicky (1971).

As it might occur in normal discourse, the sentence

9. If Mary plays tennis, she'll injure her wrist

could have more than one viable conditional interpretation. Either Mary will injure her wrist only if she plays tennis and not otherwise, or playing tennis is naturally interpreted as only one of several possible ways in which the injury might occur. Under the former interpretation, both

10. $T \supset I$

and 11. $\sim I \supset \sim T$

are true (where T and I stand for the antecedent and consequent propositions). Under the latter interpretation, only 11. alone expresses the meaning correctly. A second example might be

12. If you finish your degree, I'll
buy you a new car.

In this case, however, the biconditional interpretation seems more correct; receiving the car and finishing the degree seem to be mutually entailed. The status of such expressions as 12 was taken up by Geis and Zwicky who indicated the ubiquity of such biconditional interpretations in the presence of promises. Suggesting that such an interpretation was the result of "a tendency to perfect conditionals to biconditionals", they raised this to the level of a principle named Conditional Perfection (p. 562). This principle, they claimed, covered not only promises but also threats, law-like statements, commands, and counterfactuals (pp. 562-563). The term used to cover all these various statement classes was invited inferences.

While it has found some support in the treatment of counterfactual statements by Karttunen (1971), the Conditional Perfection analysis has not gone unchallenged. Lilje argued that the biconditional analysis should be interpreted as being context dependent (p. 540). To take Geis's and Zwicky's own original example of a promise,

13. If you mow the lawn, I'll give you
five dollars. (1971, p. 561)

it was not evident to Lilje that in all naturally occurring cases the donation of five dollars entailed a mown lawn; the statement might well be only the first in a list of responses to the question "How can I earn five dollars?". Lilje's main point here was to distinguish between pragmatic assumption and invited inference. The latter term did not properly describe a discrete class of sentences and, he further suggested, it was often the case that people made "uninvited" as well as "invited" inferences (1972, pp. 541-542). No simple answer seemed to emerge to the question of how interpretation of such conditionals might be formalized.

Fillenbaum (1974, 1975, 1976, 1978) has attempted to provide more detailed behavioural evidence for the linguistic definition of invited inferences (or inducements) and many other conditional statement types. Many psychological researchers, he has emphasized, have concentrated on the use of abstract symbols in their examination of conditional reasoning without having confronted the problems of non-generalizability when it came to the explanation of inducements, temporal, temporal-causal, non-causal contingent universals and other kinds of conditional statement. It is possible, he has argued, that if the wide range of possible interpretations of if is recognized,"one may come to see some logical 'fallacies' in a quite different light, not as 'fallacies' at all but rather as pragmatically reasonable inferences" (1974, p. 247).

In support of this claim of the natural variability of conditional reasoning, Fillenbaum conducted an experiment with undergraduates in which they were asked, first, to make judgements about the ordinariness or strangeness of instances taken from the range of possible conditional types discussed above, second, to paraphrase examples while excluding use of if and, third, to judge from pairs of sentences whether in each case the second was a natural inference from the first. To summarize Fillenbaum's findings, it appeared both that subjects were able to distinguish accurately between malformed and well-formed conditional statements and that their paraphrases exhibited a high degree of systematicity (promises, for example, were most commonly paraphrased using and (40%) and positive sentences led to far more paraphrases using then than did negatives (15% vs. 5%)). Firm evidence was thus found for the various yet systematic interpretations connected with the range of conditional statement types.

A follow-up experiment reported by Fillenbaum (1978) established, in addition to these observations, that when subjects were asked to remember anomalous conditionals, they normalized them according to their pragmatically based world knowledge. Interpretation of conditionals would therefore seem to involve the same sorts of constructive cognitive processing noted in more general discourse (see, e.g., Bartlett, 1932, Sachs, 1967, Bransford and Franks, 1971). Fillenbaum's observations have indicated the complexity of the full conditional system in natural language and have strongly emphasized the significance of a linguistic typology of conditional sentences.

Logic vs. Everyday Reasoning

Some brief mention was made in the Introduction of Piaget's proposal of an isomorphism between formal logic and natural reasoning. The idea was more fully expressed by Inhelder and Piaget as follows:

> (R)easoning is nothing more than the propositional calculus itself. Although, in the subject's thought, this calculus is linked to current speech patterns, it can be expressed symbolically in terms of the algebra of propositional logic.
> (1958, p. 315)

While the notion of a close relationship between logic and thought has been part of a long tradition in philosophy, culminating in the work of the Logical Positivists, recent approaches have been more cautious, emphasizing the many concomitant problems and complexities. Some points of especial importance for psychological investigations of syllogistic reasoning were made in an influential article by Henle (1962), part of which provided a short review of previous approaches.

As Henle indicated, the older tradition, which included the positions of Kant and Boole, had been characterized by the view that logic itself was the science of thought, in Boole's words, that "the laws of the symbols of logic" were "deducible from a consideration of the operations of the mind in reasoning" (quoted in

Henle, 1962, p. 366). Citing Cohen (1944) and Nagel (1956) as the sources of the more recent view that thought is grounded in belief than in logic, Henle reduced the central definitional problems to a series of questions as follows:

> Do errors in deductive reasoning mean that the logical process has been violated? ...does the occurrence of error mean that the syllogism is a bad one? Or can the error be accounted for otherwise? Is it possible that a process that would follow the rules of logic if it were spelled out is discernible even when the reasoning results in error? (p. 369)

Henle further developed some possible answers to these questions based on empirical data.

In Henle's experiment, graduate psychology students were required to evaluate the logical adequacy of some syllogisms presented in everyday contexts. While concentrating on discussion of individual patterns rather than normative measures, Henle distinguished several sources of reasoning error. First, subjects often "failed to accept the logical task", that is, they failed to recognize the distinction between logical validity and real-world fact. Whether or not they gave correct answers to the questions of logical adequacy, many subjects justified their answers in ways which demonstrated lack of understanding of the real substance of the questions. Second, subjects sometimes restated premises to accord with their own evaluations of conclusions; premises were sometimes normalized to their world knowledge and to subjective expectations rather than objective logical schemes (see also, Janis and Frick, above). Third, subjects often omitted mention of the intended premises in their evaluations, making apparently correct deductions based upon the wrong information. Finally, subjects occasionally added extra premises to arguments, reasoning, for example, from the given information "comic books are an evil influence" that "they should be got rid of" on the basis of the added proposition: "whatever is an evil influence should be got rid of" (p. 372). Summarizing her findings, Henle concluded:

> (W)hen subjects arrive at apparently invalid conclusions, or when they fail to spot a fallacy, they often do so because they have worked with materials different from those intended or because they have undertaken a task different from the one intended.
>
> (I)t must be concluded that the presence of error does not constitute evidence that the laws of logic are irrelevant to actual thinking. The data tend, rather, to support the older conception that these laws are widely discernible in the thinking process. (p. 373)

Henle's central point was that syllogistic form, far from being irrelevant to normal processing, was a common feature within it. Subjects appeared to reason idiosyncratically, and the major theoretical problems in describing human reasoning, she argued, centre on subjects' failure to accept the experimenter's task and the failure of the latter to recognize the nature of their misunderstanding. The interpretation put forward here was that the relation between logic and normal reasoning was fundamentally a close one. They were not, however, claimed to be equated or isomorphic in the direct sense of Piaget's proposals, and Henle demonstrated that analysis of deductive reasoning demands detailed attention to the premises actually used by subjects.

More recently, following Henle's observations, some of the more detailed questions of how a complete logical model of thought might be described have been addressed. Johnson-Laird (1975) has suggested, once again in opposition to Piagetian isomorphism, that inferences are understood in terms of psychological rather than logical schema. In particular, lexical inferences, he has argued, may well be understood in terms of spatial imagery, and neither propositional nor quantificational reasoning seem to be axiomatic in nature at all, depending upon plausibility rather than logical validity (pp. 14, 41-42). While attractive in its functionalism, however, the notion of plausibility as the basis for a model of thought has not passed without criticism. The question of the inclusion necessarily raises some complex semantic and philosophical problems. One theorist in particular, Kempson (1975, 1977), has forcefully argued, by way of detailed evidence, for maintaining a two-valued truth-functional base for the analysis of meaning and that, while pragmatic decisions may be an important part of language processing, they cannot form the foundation of a general semantic theory (1977, pp. 58-74).

One further possible solution to the problem of reconciling logic and reasoning is to maintain _both_ a logical and a psychological description and to relate the two by way of a system of mapping rules. Such a solution has been attempted by Braine (1978, 1979) who has argued that a complete model of reasoning demands both an inference-schemata description and a performance component containing programs for comprehension and reasoning strategies (1978, pp. 3-5). Turning directly to the problems of interpretation connected with conditional reasoning, Braine raised several objections to the "chameleon theory" of Wason and Johnson-Laird (see above), one of which was that any exclusively truth-based approach must take into account that an identical interpretation is given to each sentence of the forms _if_ _p_ _then_ _q_, _p_ _only_ _if_ _q_, and _if_ _not_ _q,_ _then_ _not_ _p_. As a cursory translation into ordinary language terms demonstrates, this is unsatisfactory; such anomalous sentences as "One pulls the knob out only if the television goes on" exemplify the inadequacy of the approach. Braine's radical proposal has been to deny _any_ equation between the connectives of natural language and the truth-functional account. His alternative is stated as follows:

> The logical function of if...then is to state inference rules. If...then... is taken to be a grammatical frame such that, when the blanks are filled in with propositions (say, α and β) the result is the following inference rule
>
> $$\frac{\alpha}{\beta}$$
>
> That is, if α has been established, then β can be immediately concluded.
> (p. 8)

This alternative behavioural formulation Braine relates to standard propositional logic by systematic translation, arguing in the process that the characteristics of natural and standard logic are similar. Indeed, "natural and standard propositional logic", he asserts, "are the same system on different foundations" (p. 18).

Essentially, Braine has provided a model which is both dualistic in its distinction between psychological and logical foundations and cast within a functionalist framework. Like Johnson-Laird, Braine has raised strong objections to Piagetian isomorphism. He has argued that the operational schemata such as those controlling the combinations and permutations of logical relations in the purported formal-operational lattice system, must be thought of as belonging to a quite different and separate system from the logic itself. His conclusion has been that Piaget's empirical research itself provided better evidence for the operational schemata than for the logical system, and it was partly upon this basis that Braine has made inferences rather than axioms the centre of his model.

Underlying Rationale of the Study

Both the history of research into syllogistic reasoning and analysis of conditional propositions themselves suggest linguistic deductive processing to be complex and interactive. The background of theoretical debate on the appropriacy of logical models to the description of human reasoning, however, further suggests continued examination to be viable and interesting if such models are approached flexibly and used heuristically.

Taken as a whole, the linguistic conditional system is extremely varied and goes far beyond the bounds of the propositional calculus. There are many concomitant demands made on cognitive processing, demands which vary with context and which range in kind from the purely logical to the purely pragmatic. While previous research has become increasingly sensitive to the various kinds of linguistic and contextual properties which have effect on reasoning, and while the presence of a theoretical shift towards functional, context-sensitive analysis of children's reasoning has been noted (see Chapter One, above), there has to date been no systematic attempt to relate the complexity of logical tasks to the characteristics of the discourse contexts in which they are embedded. Considering the evidence of spontaneous logical processing recently found, for example, by

Donaldson (1978), and of both pragmatic and metacognitive processing, it seems especially important to extend the previous research by exploring the effects of narrative variation on logical processing. In particular, it seems that logical processing may depend more upon the accessibility to subjects of the narrative discourse 'worlds' in which problems are set than upon propositional complexity per se. If this is the case, then logical processing will be to some degree dependent upon familiarity with such discourse worlds and the extent to which they make sense to subjects. It is possible that children's logical processing may be more secure when they deal with imaginative rather than with factual material, a hypothesis which, if supported, suggests some necessary reassessment of the orthodox developmental model and, indeed, of the distinction between abstract and concrete content itself.

By exploring these ideas in the present study, it is hoped to provide some explanation of the relationship between the development of conditional reasoning skills as they relate to certain linguistic and contextual variables. The particular variables chosen for study and the development of test materials are described in the following chapter.

CHAPTER THREE

DESIGN, PROCEDURE, AND HYPOTHESES

Independent Variation

Although previous studies have examined a wide range of mode and content effects in syllogistic reasoning, no systematic research has been conducted on the contextual effects of narrative discourse type on such logical processing. On this basis, three sources of independent variation were selected for the testing conducted in the present study: grade level, passage type, and logical problem type. The possibility of sex differences in narrative preference was also examined.

Subject Sampling

Grades 4, 6, and 12 were chosen on the basis of their appropriacy for observation of any apparent distinctions between concrete- and formal-operational behaviour relating to the task and of any possibly interesting transitional characteristics. Grade 4 subjects were selected on the basis of pilot testing as the youngest potential candidates for taking what was necessarily a fairly exhaustive test demanding about fifty minutes concentration. The grade 12 population was chosen as the subset of the adult population as this allowed for a balanced classroom testing procedure for all subjects and constrained the domain of generalization to that of school students.

Subjects were all from elementary or secondary schools within the school districts of Pentiction and Prince Rupert, British Columbia. All classes tested were heterogeneously grouped. Variations in classroom organization and in teacher judgement about student participation demanded a flexible approach to sampling, especially at the grade 4 level. It was often the case that teachers recommended omitting certain children on grounds of particular known limits of linguistic ability or concentration. While suitable reading level scores were not available for each subject, these omissions were encouraged by the experimenter in order to ensure that no child for whom the task presented serious linguistic problems was forced to take the test.

The exclusion of all tests of subjects for whom English was not the first language and the strict admissibility criteria (see Scoring, below) further guaranteed that no data were taken from subjects experiencing linguistic or concentration problems. These procedures meant that Grade x Sex cell sizes were inevitably unequal. It appeared, however, that grade level sample sizes accurately reflected proportions in the populations of interest. Suitable statistical procedures were adopted to reflect these unequal cell frequencies (see Chapter Four, below).

In all, 41 grade 4 subjects (26 female and 15 male), 60 grade 6 subjects (32 female, 28 male), and 72 grade 12 subjects (45 female, 27 male) took the test. A high proportion of grade 4 children failed to meet the requirements of test completion outlined below (see Scoring), while a larger proportion of grade 6 and almost all grade 12 subjects met these requirements. In the end, 22 grade 4 subjects (13 female and 9 male), 47 grade 6 subjects (25 female, 22 male), and 68 grade 12 subjects (43 female, 25 male) successfully completed the task. In order to achieve strict proportionality and a slightly greater degree of balance between the groups, three grade 6 and two grade 12 subjects were eliminated at random from the test sample.

Passages

The construction of the three test passages and of the logical problems based upon them was closely related to considerations introduced in the previous chapters. The starting point for determining textual and logical variation lay in the distinguishing properties of conditional statement types themselves.

In selecting from the range of these statement types, the following three seemed to provide especially interesting contrasts in their particular demands upon reasoning. The first type, defined as abstract, involved the pairing of antecedent and consequent propositions bearing only an arbitrary relationship, that is, a relationship to which neither pragmatic nor empirical information contributed. The second type, concrete, allowed use of real-world empirical knowledge in its interpretation of antecedent and consequent propositions. The third type, inducement, required the use of practical real-world understanding for the interpretation of interpersonal promises and threats. For convenience, these three types of conditional statement have been abbreviated, respectively, AB, CO, and IN.

These three conditional statement types were seen to correspond to three parallel narrative text types: Fantastic (F), Realistic (R), and Contractual (C), in the sense that it was the same characteristics underlying AB statements which were also more generally those of F texts, the same characteristics of CO statements which were embodied in R texts and the same characteristics of IN statements which were to be found in Contractual material. More specifically, the distinguishing feature of an F text was operationally defined as its representation of a discourse world in which relations are predominantly arbitrary or abstract, of an R text as its representation of a discourse world in which relations bear empirical meaning, and of a C text as its representation of a world in which the principal demands are made on pragmatically based understanding of promises or threats.

Three contrasting texts were constructed; a Fantasy text, entitled The Black Hole, based upon the novel of the same name, a Reality text, entitled The Barn Owl, describing various features of the bird's natural capabilities and habits, and a Contractual text, based upon the inducements normally represented in a well-known television game show entitled The Joker's Wild. The latter two texts were written by the experimenter for the study and were not adapted from other existing material. These texts, balanced for word length, served as the base from which the content of all logical test questions was generated, and provided the essential discourse contexts for the comprehension and solution of all problems. Three versions of each text were constructed to match the grade 4, 6, and 12 reading levels via Dale-Chall readability measures. Details of such measures are to be found, together with a description of all other test materials, listed in Appendix B.

Logical Problems

Earlier studies had included all the basic types of syllogistic problems (MP, MT, AC, and DA) and had also explored the effects of negation. These studies, however, had opted either for overall tests of recognition (of correct conclusion or of logical inappropriacy), or for production of correct conclusions. In the present study, a fuller range of processing demands were made on subjects by introducing not only MP, MT, and negation problems (examination of AC and DA fallacies was left to their natural incidence as incorrect responses to MP and MT problems) but also requiring of them both production and recognition. These more rigorous requirements were implicit in the general form of the test questions, which were designed to elicit either a) a subject's selection, from a multiple-choice set, of the conclusion to a syllogism based upon his understanding of the passage and some additional information, together with b) his production of the second premise in justification of this first choice, or c) recognition that a given question did not provide sufficient information upon which to base a logical answer. Stated most generally, a test question sequence took the following form:

1. presentation of a passage
2. presentation of additional information (the first premise of a hypothetical syllogism, either based upon the passage or, in the case of recognition problems, bearing no relation to it)
3. selection of the correct conclusion from a set of five multiple-choice possibilities
4. provision of the appropriate second premise of the syllogism or, in the case of recognition problems, of the statement "insufficient information".

In order to test the possibility that measurable differences might be more easily solved when their content was coordinated not only in reference but also in underlying semantic characteristics with passages, both MP and MT problems were subdivided for each passage according to the classification of their first premises as AB, CO, IN. Hence, for each passage, there were six basic MP and MT forms, yielding eighteen Passage x Logical Question Type combinations (F, R, C, x MP/AB, MP/CO, MP/IN, MT/AB, MT/CO, MT/IN). In addition, each question set contained one MP problem containing negated antecedent and consequent propositions and two recognition problems, one in negative and one in positive form, for which the correct answers were "can't tell" followed by "insufficient information". The negative MP problems took the conditional statement form coordinate with the passage on which it was based, whereas the recognition problems were unspecified with respect to their AB, CO, and IN contents and were contrasted solely in terms of negation. Table 1 provides a summary of treatment variables, levels and associated abbreviations. In all, the classifications yielded twenty-seven Passage x Logical Type test questions.

Following presentation of each passage, subjects' choices of conclusions were made from multiple-choice sets of five. Each such set was constructed to include all of the following possible kinds of answers:

1. a correct conclusion based on the materials;
2. an incorrect conclusion specifically denying

Table 1.

Summary of Treatment Variables and Levels

Treatment	Type	Abbreviation
Logical Problems	Modus Ponens - Abstract	MP/AB
	Modus Ponens - Concrete	MP/CO
	Modus Ponens - Inducement	MP/IN
	Modus Ponens - Negative	MP/NE
	Modus Tollens - Abstract	MT/AB
	Modus Tollens - Concrete	MT/CO
	Modus Tollens - Inducement	MT/IN
	Recognition - Positive	RE/PO
	Recognition - Negative	RE/NE
Passages	Fantastic	F
	Realistic	R
	Contractual	C

some proposition presented as true in the passage or additional information;

3. an internally irrelevant conclusion, replicating a proposition from the passage yet which did not appear in the additional information;
4. an external irrelevant conclusion, a proposition judged to be a reasonable supposition but not appearing in the passage or in the additional information;
5. a can't tell option, which was followed by subjects' written justifications.

Metacognitive Questions

Following each of the three passage x logical question sets came an extra question designed to elicit information about subjects' metacognitive awareness of the task variables. This question asked subjects to make one further choice from a set of five, in this case containing possible descriptions of the nature of the narrative found in the passage ranging from *actual* to *imaginary*. Finally, following presentation of all complete question sets, subjects were asked to make a multiple-choice judgement about the nature of the entire task, about which of their abilities they thought the questions had tested best.

All questions were placed in a single booklet in which subjects recorded their answers. A second booklet contained the passages, preceded by a short example test sequence which was presented before each test session. The order of presentation both of question types within passage sets and multiple-choice conclusions within questions was randomized.

Instructions to Subjects

Pilot testing of the materials on individual subjects at each grade level indicated that a short example sequence rather than a formal prescriptive announcement ensured the speediest and most secure understanding of the task requirements. Accordingly, an informal and interactive approach was adopted at each level.

Having received the two test booklets, subjects were first told that the test was not concerned with success or failure in school and that it was solely of research interest. Subjects were told in advance that they would themselves be required to make a multiple-choice judgement about the nature of the test at the end and so would not be informed about its precise objectives. Subjects were then referred to the example passage and questions in the first booklet. This passage was read out loud (generally by a willing subject) and the four example questions, covering MP-Positive, MP-Negative, MT, and Recognition types, were gone through in order with suitable explanation of the correct answers. This explanation excluded specific mention of logic or reasoning but heavily emphasized the necessity of using both the additional information statement and the passage information in answering. Subjects were told that the test would take them about fifty minutes of a one hour time limit to complete and that they should work steadily through to the end, omitting any questions which they found unanswerable and filling in both parts of answers wherever possible. They were told to raise their hands for help with any words not known to them. It was stressed that continual use of the passages for reference during the test was both permitted and encouraged. Following this, the first passage was read out loud (once again, generally by a subject) and subjects were then left to complete the test in their own time.

Scoring of the Data

Each answer booklet collected was first subjected to the following two criteria: first, that a minimum of twenty-two out of the twenty-seven logical questions had been completed (i.e., 80% of the logical test), second, that no booklet contained a sequence of longer than four consecutive "can't tell" multiple-choice options. These stringent criteria were invoked both to ensure balanced protocols and to avoid confusing the interpretation of legitimate "can't tell" responses in the data.

The rationale underlying the assignment of scores was founded on a number of points emphasized in the review of previous theory and research. Answers clearly reflected a number of discrete capabilities: first, subjects' acceptance of the task, (Factor 1), i.e., whether or not they had understood and pursued the basic task objectives as they were introduced; second, their ability to process syllogisms logically (Factor 2) and, third, subjects' ability to utilize all the relevant textual material (Factor 3).

These three factors were proposed to underlie test performance. Optimum performance on the test was judged to involve all three and, on the basis of the number of factors present, answers were classified and scored. The full classification of answers was as follows:

1. Contextual-Logical (CL); correct logical processing in narrative context
2. Textual-Logical (TL); correct logical processing based upon the additional information statements only
3. Textual-Fallacious (TF); invalid logical processing based upon additional information statements only
4. Extra- textual-Logical (EL); correct logical processing based upon propositions not mentioned in the passage or additional information statements.

These categories comprised the set of answer types actually assigned positive scores. One point was assigned for each factor involved in these answers. In this way, responses falling into group 1 received three points, one each for acceptance of the task, logical processing and utilization of all relevant material. Responses falling into group 2 received two points, one each for acceptance of the task and logical processing. Those falling into group 3 received one point only, for acceptance of the task, and those in group 4, one point for logical processing. In addition, answers not falling into these categories and receiving a score of zero were classified for analytic purposes into:

5. *Unjustified Denials* (*UD*); denials located in answers relating to questions other than Recognition types;
6. *Justified Errors* (*JE*); trivial repetitions of passage or additional information propositions, "because it says so..." responses, or attempts to solve problems by *de facto* definitions;
7. *Erroneous Responses* (*ER*); answers demonstrating clear misunderstanding of textual propositions, reversals of positive or negative propositions, contradictions and anomalies;
8. *Incomplete* (*I*); containing either multiple-choice responses or justification, but not both.

A complete summary of these categories, together with their associated scores, appears in Table 2., where answer types are represented by their abbreviations and proposed

Table 2.

Summary of scoring for Modus Ponens and Modus Tollens problems

Answer Category	Abbrev-iation	Factor 1	2	3	Answer Score
Contextual-Logical	CL	X	X	X	3
Textual-Logical	TL	X	X	–	2
Textual-Fallacious	TF	X	–	–	1
Extra-Textual-Logical	EL	–	X	–	1
Unjustified Denial	UD	–	–	–	0
Justified Error	JE	–	–	–	0
Erroneous Response	ER	–	–	–	0
Incomplete Response	I	–	–	–	0

Table 3.

Summary of scoring for Recognition Questions

Answer Category	Abbrev-iation	Factor 1	2	3	Answer Score
Justified Denial	JD	X	–	XX	3
Incomplete Denial	ID	X	–	X	2
Textual-Logical	TL	X	X	–	2
Extra-Textual-Logical	EL	–	X	–	1
Justified Error	JE	–	–	–	0
Erroneous Response	ER	–	–	–	0

factors by their respective designations (see above).

Two further categories,

11. Justified Denial (JD)

and 12. Incomplete Denial (ID)

were included to cover the RE question types. Answers to recognition problems were treated as a discrete class on the basis of their separate processing demands and normal response probabilities. First, these answers could not easily be reduced to the three factors previously mentioned. They seemed, rather, to represent an especially demanding case of the third type of capability, i.e., recognition and acceptance of the task. Logical processing itself was not involved in these questions. Accordingly, factor 3 was doubly weighted in the scoring of these answers. Second, it seemed proper to assign a higher score to answers to those questions not containing the (redundant) justification "insufficient" than to parallel answers to other questions in which justification was essential. Such incomplete answers connected with RE question types were assigned two points rather than zero. Textual-Logical answers were also scored two points and Extra-Textual-Logical answers received one point. Since neither Contextual-Logical nor Contextual- Fallacious answers appeared following RE questions, these categories were eliminated from the RE scoring schedule (see Table 3).

Scores assigned to answers to the metacognitive questions, since they were not part of the main analysis of variance and were the basis of more tentative correlational calculations, are dealt with in a later section.

Hypotheses

The focus of the study is upon possible interactions rather than upon main effects. The following predictions were made.

1. a. There are measurable differences in logical processing between the passage types.

   b. Younger subjects (grades 4 and 6) demonstrate a greater preference for the Fantasy passage over the other types, as measured by their test scores for each passage.

   c. Older subjects (grade 12) show a greater preference for the Concrete and Inducement passages over Fantasy, as measured by their test scores for each passage.

2. a. There are measurable differences in logical processing between the types of syllogistic form included in the study.

   b. All groups demonstrate greater preference for MP over MT problems, as measured by their test scores for the two logical types.

c. Younger subjects prefer MP over MT problems to a significantly greater degree than older subjects, as measured by their test scores for the two logical types.

3. a. There are measurable differences in logical processing between problems containing negative propositions in the initial premise than those not containing negation.

   b. All groups demonstrate greater preference for problems not containing negation over those containing it.

   c. Younger subjects prefer problems not containing negation over those containing it to a significantly greater degree than older subjects, as measured by their test scores for negative and affirmative problem types.

4. a. There are measurable differences in processing between Recognition problems and other types.

   b. All groups demonstrate a greater preference for other types of logical problem over Recognition problems, as measured by their test scores for the two types of material.

c. Older subjects are measurably better at Recognition tasks than younger subjects.

5. a. There are measurable differences in processing between problems in which statements are coordinated with passages in narrative type and those in which they are not.

   b. All groups demonstrate a greater preference for coordinated material over uncoordinated material.

6. a. There is a positive relationship between metacognitive awareness both of the test variables and of the purpose of the test, and logical performance, as measured by correlation of logical performance and metacognitive scores on the test.

   b. There is a significantly greater positive relationship between metacognitive awareness and logical performance in older over younger subjects, as measured by the correlations of logical performance and metacognitive test scores for the two groups.

CHAPTER FOUR

ANALYSIS AND RESULTS

The numbers of subjects in each grade and grade x sex cell were unequal as a result of the sampling procedures adopted (see Chapter Three). As these unequal cell frequencies were related to the treatment levels themselves, they were approached as representing proportions in the population strata of interest. Suitable statistical procedures for fixed effects repeated measures designs where unequal cell sizes are proportional and orthogonally related are to be found in Winer (1971). Winer's recommendations were followed in each of the analyses of variance to be described.

Analysis of the Dependent Measures

The following two sections will deal with two analyses, that of perfect scores only (scores of 3), and that of all scores (including scores of 2 and 1). The reason for approaching the analysis of results in this way lay in its potential for revealing any interesting distinctions in the *kinds* of success achieved by the subject groups in the various conditions. In particular, it seems important to discover whether various group scores represent the kind of all-or-nothing processing reflected by perfect scores, or the more varied processing reflected by combinations of perfect and imperfect scores.

In this way, a more detailed picture can be presented of the various skills evident at each grade level.

Logical Problems: Perfect Scores

The first three-way analysis (Grade x Passage Type x Logical Question Type) took only the perfect scores as input. A summary of this analysis appears in Table 4. The F ratios demonstrated a significant main effect for Logical Question Type together with significant Grade x Passage and Passage x Logical Question Type interactions. A series of Scheffé comparisons were then conducted on the relevant means and on the basis of the experimental hypotheses.

In relation to hypotheses 2a, 2b, and 2c, the first comparison made was between the combined means for all MP and MT problems. In corroboration of hypotheses 2a and 2b, all subject groups found MP problems significantly easier than MT problems ($\bar{X}$=2.38 vs. 1.89: F=105.22; p<.01). While this confirmed previous findings, the observation was made in the absence of any apparent developmental effects, that is, in the absence of a significant AxC interaction. It appears, therefore, that MT problems made more demands on subjects at all ages tested and that there was no significant reduction in their relative difficulty for the older subjects. No support was found for hypothesis 2c, and younger subjects seemed equally adept as older subjects at solving MT problems.

TABLE 4

Summary of Analysis of Variance due to Grade, Passage Type, and Logical Problem Type: Perfect Scores

Source	df	M.S.	F-ratio
Between			
Grade (A)	2	1.494	1.881
Error	129	0.794	
Within			
Passage (B)	2	0.004	0.020
A x B	4	0.705	3.691**
Error	258	0.191	
Logic (C)	8	3.272	21.109**
A x C	16	0.171	1.1
Error	1032	0.155	
B x C	16	2.129	12.903**
A x B x C	32	0.197	1.085
Error	2064	0.165	

*$p < .05$

**$p < .01$

Following hypotheses 3a, 3b, and 3c, Scheffé comparisons were made between the combined means of all problems containing negation, including MT, ($\bar{X}$=2.01), and all others $\bar{X}$=2.31). For all subjects, the subset of negative problems was found harder than the subset of positive problems (F=76.74; p<.01). This provided support for hypotheses 3a and 3b. It should be noted, however, that the comparison between the means for MP-Negative and MP-Positive problems, even though not statistically significant, was in some contrast with the general result, subjects having found the former slightly easier. Once again, the absence of a significant AxC interaction yielded no support for hypothesis 3c, and younger subjects did not perform significantly worse on negative problems than did adults.

Comparison between the combined means for Recognition problems ($\bar{X}$=2.04) and other types ($\bar{X}$=2.20) indicated, in support of hypotheses 5a and 5b, that this type was significantly more difficult for all subjects than other problems (F=50.39; p<.01). No associated developmental trends were evident.

Further comparisons among C means revealed some interesting contrasts not contained within the experimental predictions. MP-Concrete problems as a group appear to have been easier than MP-Abstract or MP-Inducement problems ($\bar{X}$=2.53 vs. 2.25: F=35.22, p<.01), and MT-Inducement problems were more successfully answered than MT-Abstract or MT-Concrete problems ($\bar{X}$=2.02 vs. 1.82: F=85.86; p<.01). As both these observations are in isolation from contextual passage effects, they suggest possible interactions between logical forms and particular conditional statement types themselves. The observations provide a basis in the study for further linguistic hypotheses about conditional processing (see Chapter 5, below).

In partial corroboration of hypotheses 1a, 1b, and 1c, Scheffé comparisons among the AB (Grade x Passage Type) means revealed significantly better performance by grade 6 subjects on all questions connected with the Fantasy passage than by grade 12 subjects ($\bar{X}$=6.86 vs. 6.36: F=34.578; p<.01). Better performance by grade 12 subjects than by grade 4 and grade 6 subjects was also noted on questions following the Realistic and Contractual passages ($\bar{X}$=6.79 vs. 6.03: F=115.4; p<.01). However, performance on the Fantasy passage by grade 6 subjects was also significantly better than that by grade 4 subjects ($\bar{X}$=6.86 vs. 5.86: F=76.78; p<.01). These findings suggested important modification to hypothesis 1b. Grade 4 subjects were not apparently sensitive to the Fantasy passage in the same way as were grade 6 subjects. The significant Grade x Passage interactions can be clearly seen in Figure 1.

Hypotheses 5a and 5b concerned subjects' sensitivity

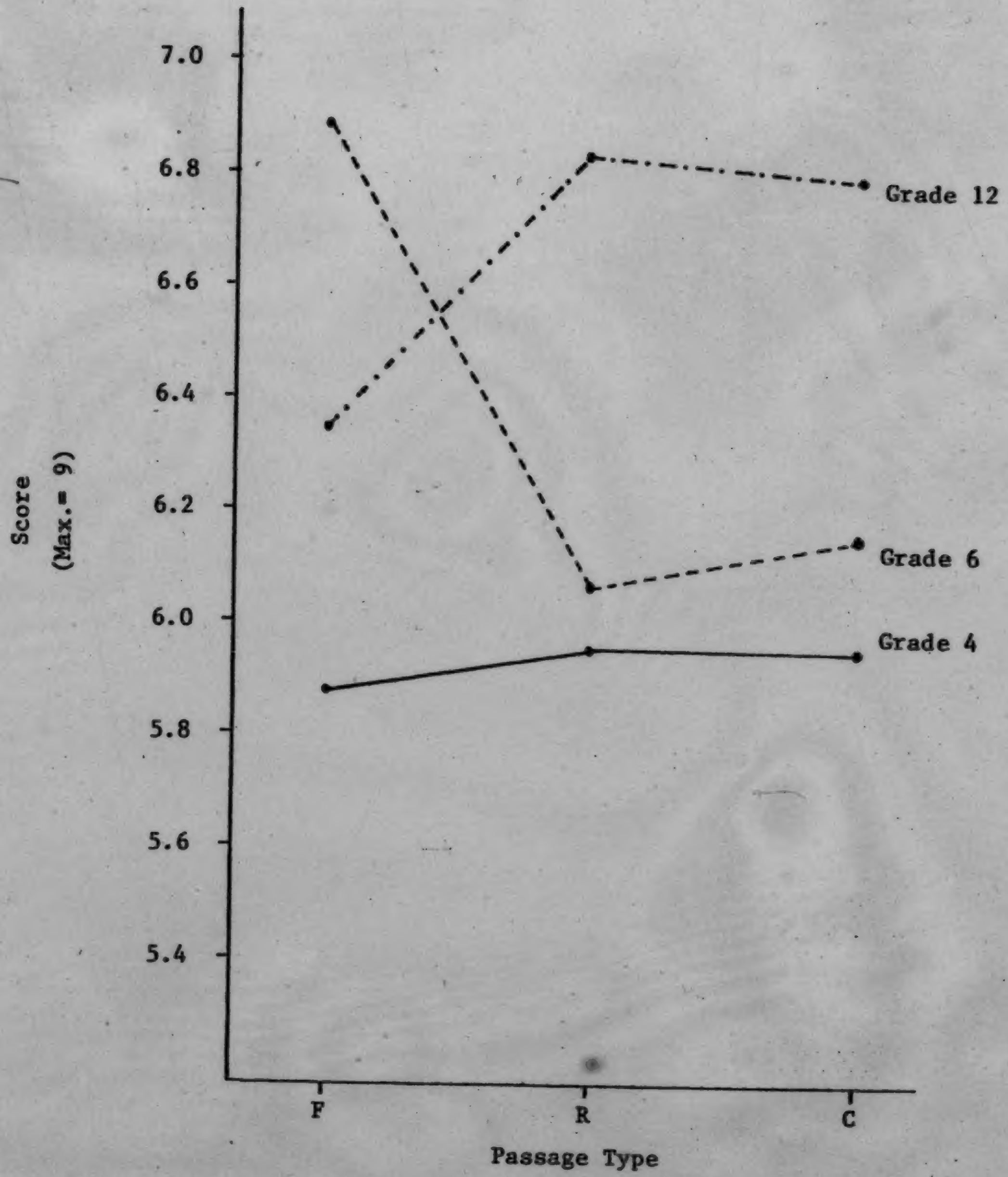

FIGURE 1

Interaction of Grade x Passage Type

to coordinated as opposed to uncoordinated materials in the problems. To test these hypotheses, a comparison was first made between the combined means for MP problems (Positive and Negative) coordinated in conditional statement type with their preceding passage ($\bar{X}$=0.81) and the combined means of all uncoordinated MP problems ($\bar{X}$=0.78) A second parallel comparison tested coordinated against uncoordinated MT problems. Neither of these comparisons reached a level of statistical significance. Indeed, further examination of the means provoked a counter-hypothesis, namely, that questions might have been answered best when contrasting in linguistic type with the narrative on which they had been based. In no case was a positive MP question coordinated with its passage the best answered of the set of three, and in one case, the Contractual passage, it was answered worst of the three ($\bar{X}$=0.803, vs. 0.856 for MP/AB and 0.902 for MP/CO). The lowest score of all in this group of questions, however, was to be found on the Inducement question based on the Fantasy text ($\bar{X}$=0.591 vs. 0.864 for the Realistic passage and 0.803 for the Contractual passage), a fact which might to some extent explain the lower overall performance on MP Inducement problems than on MP Concrete problems already noted.

A similar pattern was found with the MT problems. In no case was the coordinated question the best answered of the set of three MT problems connected with a given passage. The lack of success in answering the Inducement problem coordinated with its text was even more noticeable here, as this was the MT question receiving the lowest mean score of all ($\bar{X}$=0.43). This score was significantly lower than the other two MT-Inducement scores combined (F=56.4; p<.01).

Clearly, these results found for MP and MT problems demand further attention to the linguistic content of the individual questions, and further refinement of hypotheses concerning Passage x Logical Question Type interaction. Most of the BC interaction was attributable to variation relating to these individual question types, and no other patterns emerged which could be attributed to the combined effects of passage types and the sub-classes of logical questions.

Logical Problems: All Scores

The second three-way analysis of variance is summarized in Table 5. The only notable difference between this and the earlier analysis lay in the slight reduction of the size of the AxB interaction (p<.05) together with the appearance of a significant three-way interaction (p<.05). As suggested above, however, more detailed analysis of the interactions might yield further information about the nature of group performance.

Scheffé comparisons on these means showed, in contrast to the previous analysis, a significant difference between the combined grade 12 and grade 6 scores and the grade 4 scores on the Fantasy passage, while the significant contrast between the grade 12 and grade 6 means disappeared. This narrowing of the gap between the grade 6 and grade 12 scores in the presence of all measures served to emphasize that the distinction observed in the first analysis relied heavily on successful contextual logical processing _per se_, rather than representing any more diverse aspects of performance. The Fantasy passage, in other words, was associated with a genuine increment in logical processing in the grade 6 subjects. While the grade 12 subjects, as inclusion of the partially correct scores shows, were responsive to the passage, they simply did not perform as successfully on these questions as the grade 6 subjects. Scores on all other passages maintained the same relationships present in the former analysis, except that a very slight and non-significant increment in the performance of the younger subjects on the Realistic passage was apparent. Consideration of the AxBxC interaction did not reveal any new significant findings other than to confirm the particular effects of some isolated questions already mentioned.

Partially-Correct Answers and Systematic Errors

Two important questions arose concerning performance of subjects on those questions having scoring classifications of TL, TF, and EL, that is, those answers involving free production of logical forms falling into

TABLE 5

Summary of Analysis of Variance due to Grade, Passage Type, and Logical Problem Type: All Scores

Source	df	M.S.	F-ratio
Between			
Grade (A)	2	14.155	2.688
Error	129	5.267	
Within			
Passage (B)	2	0.408	0.305
A x B	4	3.432	2.572*
Error	258	1.334	
Logic (C)	8	20.852	16.631**
A x C	16	1.801	1.437
Error	1032	1.254	
B x C	16	14.419	11.797**
A x B x C	32	1.975	1.616*
Error	2064	1.222	

*$p < .05$

**$p < .01$

the category either of correct adherence to the valid forms of the propositional calculus (MP and MT) or of the Fallacies (AC and DA). First, did any developmental patterns emerge in subjects' tendencies to use particular valid forms and, second, were there any similar patterns in the use of fallacious forms? A complete representation of the frequency of all occurrence of partially-correct answers and of all unscored error responses appears in Table 6. As may be seen, the answer to the second question was clear: in the presence of only two instances of fallacious forms in the entire study, one each at the grade 6 and grade 12 levels, it appeared that subjects had not reasoned according to these logical patterns when producing justifications in the study. This was in some contrast to earlier results following recognition tests (cf. Roberge, 1970). The relations between measures on logically valid but acontextual answers were more complex and demanded more detailed consideration.

In order to explore the partially-correct answers in more detail, Z statistics were used to compare sample proportion scores. First, comparisons were made between the proportions of all scores not recorded as completely correct responses represented by the TL, TF, EL, and ID answer categories (see Table 7). Two-tailed tests established that while TL answers had significantly increased with age (grade 12 > grade 4; Z=4.382; p<.01: grade 6 > grade 4; Z=2.5; p<.05: grade 12 > grades 4 and 6

TABLE 6

Partially-Correct Answer and Error Response Frequency Statistics

(Reported in terms of proportions of all scores)

	Answer Type							
	TL	TF	EL	ID	JE	ER	I	UD
Grade 4	0.06	–	0.02	–	0.08	0.03	0.01	0.12
Grade 6	0.06	–	0.01	0.01	0.07	0.04	0.02	0.05
Grade 12	0.08	–	–	0.01	0.05	0.02	0.03	0.08

combined; Z=3.94; p<.01), EL answers followed the opposite trend (grade 4 > grade 12; Z=4.248; p<.01: grade 6 > grade 12; Z=2.67; p<.01: grades 4 and 6 > grade 12; Z=3.617; p<.01). This seemed to demonstrate a significant increase in the production of acontextual logical forms with age together with a decrease in use of information extraneous to the task, a finding not inconsistant with the general supposition of increased logical performance with age (hypotheses 2c, 3c, 4c,), but not apparent in the analysis based on perfect scores.

The second set of comparisons concerned the particular varieties of valid logical argument used by subjects in each grade. Four possible production forms emerged from the data, the three which had actually entered into the design of the test instrument (MP-Positive, MP-Negative and MT) together with one other, a form of Modus Tollens in which the proposition itself had been negated before valid denial of the truth of the consequent had proceeded. Occurrences of such forms, considered too difficult to introduce into the experimental tasks themselves, forced a further classification. Accordingly, in Table 9, Modus Tollens scores are divided into two; MT-Positive, representing instances of denial of positive propositions, and MT-Negative, representing instances of negated proposition followed by denial. Table 8 contains the proportions of all MP scores and all MT scores taken together.

TABLE 7

Partially-Correct Answer Frequencies

(Reported in terms of proportions of all error scores)

	Answer Category			
	TL	TF	EL	ID
Grade 4	0.152	-	0.052	0.008
Grade 6	0.237	0.003	0.024	0.029
Grade 12	0.301	0.002	0.004	0.017

TABLE 8

Textual-Logical Answers: Proportions of Modus Ponens and Modus Tollens Responses

	Argument Type	
	MP	MT
Grade 4	0.499	0.501
Grade 6	0.616	0.384
Grade 12	0.781	0.219

Noticeable in the total MP and MT scores (Table 8) was the increase in the occurrence of MP forms with age, and the corresponding decrease in MT forms. Significant Z scores relating to these comparisons were, for the MP forms, (grade 12 > grade 6; $Z=2.55$; $p<.01$: grade 12 > grades 6 and 4 combined; $Z=3.78$, $p<.01$) and, for the MT forms; (grade 4 > grade 12; $Z=3.426$; $p<.01$: grade 4 > grades 6 and 12 combined; $Z=2.447$; $p<.05$). The rather surprising direction of these results was in some contrast to the hypotheses concerning the generally expected higher incidence of success both on MT and Negative problem solving in the older subjects. This will be discussed in a later section (see Chapter Five, below). Turning to the breakdown of results for the sub-categories, it was found that although the highest proportions for negative forms corresponded to the younger groups (MP-Negative in grade 6 and MT-Negative in grade 4), these differences were not significant. The main contribution to the directions of the overall MP and MT findings seemed to have been contributed by the results for MP-Positive (grade 12 > grades 6 and 4; $Z=4.32$; $p<.01$) and for MT-Positive responses (grade 6 > grade 12; $Z=2.921$; $p<.01$: grade 4 > grade 12; $Z=3.491$; $p<.01$).

In reference to the systematic error proportions presented in Table 10, only one significant comparison was evident, that between the proportions of responses

TABLE 9

Textual-Logical Answers: Proportions of Modus Ponens and Modus Tollens Positive and Negative Responses

	Argument Type			
	MP+	MP-	MT+	MT-
Grade 4	0.236	0.263	0.369	0.132
Grade 6	0.260	0.356	0.288	0.096
Grade 12	0.518	0.263	0.125	0.094

TABLE 10

Unscored Error Frequencies

(Reported in terms of all error scores)

	Answer Category			
	JE	ER	I	UD
Grade 4	0.20	0.084	0.016	0.267
Grade 6	0.28	0.143	0.072	0.215
Grade 12	0.178	0.081	0.107	0.307

classified as Incomplete. Here, the grade 12 group contributed relatively more than the other two groups combined ($Z=3.77$; $p<.01$). All other categories seem to have been evenly distributed across the error responses.

Sex Differences

Although sex differences were not a primary concern of the study and little evidence had been found for them in previous studies (e.g. Hill, 1960), it was thought worthwhile to test for them here in the presence of narrative material which might be connected with sex preferences. Accordingly, a further analyis of variance was performed, taking all of the subjects' scores as input.

While no significant Sex main effect or Sex x treatment interactions were found, a significant Grade x Sex effect was apparent in the data. *A posteriori* Scheffé comparisons on the AB (Grade x Sex) means determined significant differences between the performance of female and male subjects at both the grade 4 and grade 6 levels. Grade 4 girls performed better in general than grade 4 boys, and grade 6 boys better than grade 6 girls. No parallel difference was found at the grade 12 level.

While these findings suggest that sex differences did indeed play some part in the test, they are difficult to interpret in more detail in the absence of significant Sex x treatment interactions. The observed difference at the grade 4 level seems to fit in with the orthodox claim of girls' faster linguistic development than boys', and yet the grade 6 results are in clear disagreement with this general pattern. A variety of possible causes, such as the different individual levels of classroon concentration and their relation to wider sociological differences, could be proposed to underlie such effects. In the limited context of the present study, however, such proposals would amount to mere speculation about factors that are indeterminate with respect to the experimental techniques adopted. Moreover, the difficulty of interpreting evidence of sex differences is compounded by the absence of more detailed general research into underlying causal factors, a problem which has been well noted, for example, in a recent study into the development of composition skills across the same age range examined here (Crowhurst, 1977, pp. 36-37). Accordingly, while the results are potentially interesting for later investigation, in this study the topic of sex differences was eliminated from further consideration.

Metacognitive Scores

Question 10 following each passage required subjects to choose the one from the following set which best described the narrative: actual, realistic, possible, impossible, or imagined. The question following the entire test required subjects to judge what had been best examined by the tasks: linguistic ability, mathematical ability, comprehension ability, or logical ability (See

Appendix B).

The scoring schedule for these responses was established by the experimenter in consultation with an independent rater on the basis of subjects' approximation to the following set of judgements. Responses to the Fantasy passage were scored if the selection were either imagined or impossible, two points for the former, which was judged to be the best answer, and one point for the latter. Responses to the Realistic passage were correspondingly scored two for actual and one point for realistic. Responses to the Contractual passage were scored two points for possible, one for imagined, and one for realistic. These scores were judged to reflect the most accurate description of the characteristics of the various discourse worlds presented and thus to represent valid metacognitive measures. The additional complexity to be found in the schedule for the Inducement passage arose out of the more ambiguous nature of its narrative qualities. For this passage, the categories realistic and imagined were not considered to be mutually exclusive. Rather like the Historical Novel, the passage was judged to be "based on fact." The best answer to the final question was considered to be logical ability, which was scored three points, the next best to be comprehension ability, scored two points, and the third best to be linguistic ability, scored one point.

The hypotheses underlying the measurements conducted on the metacognitive responses (hypotheses 6a, 6b,) expressed the anticipated correlations between subjects' performance on the logical tasks and their metacognitive scores. Accordingly, Pearson Product Moment Coefficients were calculated for subjects' total metacognitive scores and total logical problem scores. These correlations were calculated within each grade and for each of the passage types. Rather surprisingly, no significant correlations emerged. The measures ranged from r=0.29 (grade 6 total score comparison) to r=0.38 (grade 4 and grade 12 total score comparisons). Clearly, the metacognitive measures taken in the present study were either insensitive to the phenomena in question or represented a genuine behavioural neutrality. These alternative possibilities can only be a matter for speculation in the absence of any more meaningful data. The question following each passage on topic recognition was equally well answered by all groups and provided no more variation than did the correlation scores. These matters are left for more general discussion (see Chapter 5).

Summary of Findings

The three-way ANOVA on perfect logical problem scores revealed a significant main effect for Logical Question Type and significant Grade x Passage and Passage x Logical Question Type interactions. Further *a posteriori* examination found confirmation for hypothesis 2b, that subjects would find MP problems in general easier than MT problems, but no support was found for hypothesis 2c, that the gap in scores between the two problem types would narrow with age. Support was found for hypotheses 3a and 3b, that subjects would find problems containing negation in general more difficult than those not containing it, but it was also noted that MP-Negative problems were actually answered slightly better than MP-Positive problems. Again, no support was found for the developmental hypothesis 3c, that the performance gap would narrow with age. Hypotheses 4a and 4b, that subjects would prefer MP and MT over Recognition problems, were confirmed, but once again, no evidence of developmental trends was found.

Concerning the Grade x Passage interaction, in corroboration of hypotheses 1a, 1b, and 1c, Scheffé comparisons revealed significantly better performance by grade 6 subjects than by grade 12 subjects on the Fantasy passage, together with better performance by grade 12 subjects than both the other groups on the Realistic and Contractual passages. No support was found for the notion that subjects would prefer coordinated over uncoordinated materials (hypotheses 5a and 5b). Rather, the data seemed to provoke the counter-conclusion, that they preferred uncoordinated materials.

The three-way ANOVA on all logical problem scores revealed, in general, a similar pattern to the previous analysis, except that the size of the difference in performance on the Fantasy passage between grade 12 and grade 6 subjects was diminished. This seemed to emphasize the fact that the observed superiority of the grade 6 over the grade 12 and grade 4 subjects evident in perfect responses had been due to improved logical problem solving *per se*, rather than due to a combination of logical and contextual processing characteristics.

Examination of the distribution of partially-correct answer categories was conducted by way of Z statistics comparing the proportions represented. In some contrast with previous findings, it was found that while the incidence of Textual-Logical responses had, in general, significantly increased with age, younger subjects actually produced more Modus Tollens arguments than grade 12 subjects, and that the reverse was true for Modus Ponens forms. Extra-Textual-Logical answers also decreased with age, consistent with the general supposition of a corresponding increase in contextual-logical behaviour. In breaking down the argument types further, it was found that the relationship between grades and production of MP and MT forms was accounted for principally by the positive versions of each but that, somewhat surprisingly, the younger groups had produced more negative versions, even though this latter contrast did not reach a level of statistical significance. The only result of interest arising out of comparisons between the proportions of unscored error types was that grade 12 subjects contributed significantly more Incomplete answers than the younger subjects. All other unscored error categories were evenly distributed across the grades.

One final four-way ANOVA was performed on the data (Grade x Sex x Passage Type x Logical Question Type). In this analysis, a significant Grade x Sex effect was found, and a posteriori testing established this to be attributable to the better performance of females in grade 4 and of males in grade 6. No difference was found at the grade 12 level. While suggesting some general effect of sex differences in the test, in the absence of further evidence of Sex x treatment variable interactions and of more substantial related developmental theory, the underlying causes could not be further analyzed.

The results based on metacognitive measures were inconclusive. Either the measures themselves had been insensitive to the phenomena of interest or the phenomena themselves were inconsequential. Further discussion of these possibilities can only be speculative in absence of more revealing data.

CHAPTER FIVE

DISCUSSION AND IMPLICATIONS

The central empirical questions initially raised in this study concerned the effects on deductive processing of narrative and logical variation in the test materials, while the theoretical questions focussed upon some of the wider problems of developmental theory in the area. Foremost among these latter problems were those associated with the assessment of reasoning abilities by the standard of the propositional calculus, with any proposed isomorphism between logical and psychological systems, and with the structuralist distinctions found at the core of Piaget's theory. Further consideration is given in this chapter to the matters of logical and linguistic interest, followed by discussion of the theoretical concerns.

Logical variation

The demands made on subjects in answering the logical questions in the present study differed significantly from earlier studies in several respects. First, the basic form of the questions was enthymematic, that is, subjects were required to produce a premise in each syllogism which had been suppressed in the question materials themselves. This was in strong contrast with all previous studies, including those by Hill (1960) and Roberge (1970), in which subjects' responses were limited to multiple-choice judgements about the correctness of argument forms presented. The testing technique also differed from studies such as those by Wason and Johnson-Laird (1972), and Henle (1962), in which answers were based upon presentation of complete syllogistic forms in the questions. It differed from Kuhn's (1977) approach in that the additional information premises introduced in the present study demanded that subjects work beyond the narrative information, using the passages as bases for inference and conclusion rather than as the source of conclusions themselves. These contrasts, together with the wide range of logical problems included, resulted in a broad and rigorous test of deductive processing founded on _productive_ rather than _recognitive_ skills. The procedures, however, also offered some basis for comparing production and recognition responses. Some examples of subjects' responses as they actually appeared in answer booklet format can be seen in Appendix C.

The first important finding based upon these new testing procedures was that Modus Ponens forms were found easier than Modus Tollens forms at each grade level. This finding is in contrast with that of Roberge (1970), who detected the same relationship in grades 4 and 6, together with a significant reduction of the difference between the two argument forms in the performance of older grade 8 and 10 subjects. The present results suggest that, as a production form, MP is found to be consistently easier.

Even more interesting, however, is the strong contrast between younger and older subjects in their Textual-Logical responses, those incorrect responses given when they failed to utilize all relevant information properly. Two typical examples from the significantly larger set of Modus Tollens answers provided by the younger subjects are as follows:

1. (grade 4 response to question R5)

   If the barn-owl often sits on fences, the farmer shouts at him

   The farmer does not shout at him

   The barn-owl does not often sit on fences.

2. (grade 6 response to question F9)

   If Pizer got to the control centre first, he got a reward from the captain

   Pizer did not get a reward from the captain

   Pizer got to the control room last.

Example 1 can be contrasted with a typical adult Modus Ponens TL response to the same Recognition type question:

3. If the barn-owl often sits on fences, the farmer shouts at him

   The barn-owl often sits on fences

   The farmer shouts at him.

Further interpretation of Modus Tollens processing depends upon the recognition of an important distinction between the two underlying operations involved. These operations, namely, denial and negation, are related yet discrete. In the solution of such problems, the first step is always denial of the truth of the consequent. This operation was evident in subjects' adherence to narrative context, together with the perception and use of relevant propositions. The operation involved negation of the consequent but, in its appeal to points of reference external to the additional information statements themselves, went beyond any simple negative transformation. This first step in the MT sequence is followed by the simple application of negative transformation to the antecedent proposition, a proposition which in the test materials was represented in the question itself, making few demands on memory or narrative inference.

This distinction suggests that the lesser use of Modus Tollens forms by grade 12 subjects is explained by their recognition of the additional complexity connected with denial and a concomitant reluctance to enter into such processing. In contrast, the younger subjects, not recognizing this complexity, perhaps tended to reduce denial to negation, the processing of which, as the slight preference for MP-Negative over MP-Positive problems in the perfect-score data suggests, came naturally to all subjects. In the immediate presence of two propositions upon which negative transformations could easily be performed without appeal to the narrative context, it seems that younger subjects may have taken the opportunity.

This interpretation of the distinction between older and younger subjects' MT responses is also consistent with the frequency of Extra-Textual-Logical answers. If, as suggested, one of the central underlying reasons for grade 12 subjects' avoidance of the form was their recognition of complexity associated with the contextual demands, then this recognition might also explain their exclusion of irrelevant propositions. Some examples of younger subjects' EL answers, cast in full syllogistic form were:

4. (grade 4, question R6)

If the rabbits ruin the farmer's crops, the barn-owl sometimes feeds on them

The rabbits ruin the crops

The barn-owl sometimes feeds on rabbits.

5. (grade 6, question C5)

If you don't answer the question about the spider correctly, there is no clapping

You don't answer the spider question correctly

There is no clapping when you answer the spider question.

While both these syllogistic forms are closely related to their respective narratives, the initial premise introduced into each lies outside the bounds of any information given. Each such premise, an extrapolation from the materials, introduces new extra-textual inference as the basis for correct Modus Tollens processing. Older subjects, as indicated, were not prone to making such extraneous inferences.

The distinctions assumed to underlie Modus Tollens responses are more difficult to justify in the presence of the significant number of MT-Negative responses in the younger groups, for here denial and negation were apparently combined into highly complex form and yet handled successfully. Two examples of these responses are:

6. (grade 4, question C10)

   If Jack Berry is not wearing a blue shirt, then the policeman does not have gray hair

   The policeman has gray hair

   Jack Berry is wearing a blue shirt.

7. (grade 6, question F3)

   If Vincent was not silver-coloured, the control centre was not warm

   The control centre was warm

   Vincent was silver-coloured.

Both of these forms appear to represent instances of denial overriding simple negative processing. For each question, MP-Negative responses would have been equally appropriate (while still being classified as Textual-Logical), and yet on such occasions younger subjects opted for transformations from negative into positive forms. This behaviour may not be as anomalous as it appears, however, if it is recognized that these latter transformations are indeed simple reversals and do not really involve denial any more than the TL/MT answers previously described. The MT-Positive and MT-Negative forms are logically identical with respect to denial for in neither case is an appeal made to contextual information. The difference is in the presence in MT-Negative of two instances of double negation $(\sim\sim q, \sim\sim p)$, a sequence which, if the tendency towards voluntary negative transformation in younger subjects is correct, is also quite consistent.

The design of the test materials and, specifically, the necessarily limited scope of the multiple-choice conclusions, effectively reduced the likelihood of logically fallacious responses. Nevertheless, two instances of the Fallacies were found in the data, both involving violations of the answer format. These instances were

8. (grade 6, question C9)

> If Jack Berry is not wearing a blue shirt, then the policeman does not have gray hair
>
> Jack Berry is wearing a blue shirt
>
> The policeman has gray hair.

9. (grade 12, question F3)

> If Vincent was not silver-coloured, the control centre was not warm
>
> The control centre was not warm
>
> Vincent was not silver-coloured.

Both examples, 8 (DA) and 9 (AC), suggest that the subjects actually reversed the procedure of choosing a conclusion followed by a justification. Instead, they used a multiple-choice proposition as the second premise. The evidence for this reversal was to be found in the actual language used in the answers. The grade 6 subject first chose the second premise, following this with the written form "_then_ the policeman doesn't have gray hair," and the grade 12 subject concluded " _so_ Vincent was not silver-coloured." Although both of these responses represent interesting examples of fallacious reasoning, the departure from normal test procedure and the absence of greater opportunity for production of the Fallacies throughout the test make more certain interpretation difficult.

The facts that no developmental effect was found connected with Recognition responses and yet that these questions were generally less well answered than MP questions suggest that this mode of questioning is in itself more demanding. As proposed in the outline of the scoring rationale, Recognition-Error questions in the test primarily involved subjects' concentration upon the contextual aspects of the task, upon recognition that neither denial nor affirmation of additional information propositions was applicable. Possibly, then, Recognition questions called for a cognitive shift away from the production pattern associated with the majority of test questions. Moreover, recognition of the impossibility of propositional denial or affirmation itself demands both an act of matching additional with contextual information and a formal act of denial. These requirements bear great similarity to those underlying the relatively more difficult Modus Tollens problems previously discussed.

In summary, the overall pattern of subjects' logical processing leads to the following conclusions. First, ability to perform simple syllogistic deductions correctly seems to be equal in all groups tested. Developmental differences are located, rather, in those abilities which accompany deductive processing but which are not central to the logical forms themselves. Principal among these extra-logical abilities are the perception of and concentration upon relevance, together with the recognition of what are and what are not more difficult forms, especially in the presence of denial. Second, propositional negation in itself appears not to provide any additional cognitive burden. The results suggest, on the contrary, that negation in both antecedent and consequent propositions may in certain contexts have some kind of enhancement effect, especially for younger subjects. It is formal denial rather than grammatical transformation which seems to make the more severe processing demands, and the Textual-Logical responses in the study indicate increasing ability with age to recognize the associated logical complexities, even though no significant differences were found concerning denial in successful (perfect-score) Modus Tollens processing. In this way, the observations made support and extend the contextualist approach to the assessment of reasoning. Across the age range tested, contextual processing and the perception and use of relevant information, rather than processing of logical sequences per se, appear to be the abilities most crucial for the further analysis of developmental trends.

Narrative and Conditional Statement Variation

The salience of the Fantasy passage for the grade 6 subjects, contrasted with its difficulty for grade 12 subjects represents one of the most interesting findings in the study, since the related responses most clearly emphasize the significance of contextual variation in assessing the development of reasoning abilities. The apparent absence of any additional sensitivity in grade 4 subjects for the Fantasy passage, however, serves to indicate the likely complexity of developmental interactions. The uniformity in the improved performance of the grade 6 subjects across the logical categories represented further demonstrates the effect of the narrative variation *per se*.

Further research is clearly needed before the details of subjects' preferences for narrative frames can be fully described. Nevertheless, some tentative explanations for the differential effects of passages on logical processing can be offered in terms of possible relations established between subjects, the matters referenced in passages, and the discourse worlds represented by particular narratives.

As previously suggested, perfect score responses demanded a combination of three abilities - acceptance of the task, logical processing, and utilization of context. From an information-processing perspective, these abilities are themselves closely related to the factors of memory and attention underlying all such comprehension tasks. If, as seems likely, the grade 6 subjects strongly preferred the Fantasy passage, and the grade 12 subjects rejected it, on the basis of their level of willingness to identify with the subject matter, that is, to enter the world of the narrative, then successful processing might to some degree be explained in terms of the cognitive 'distances' involved. Expressed in the form of a metrical analogy, acceptance of and entry into a world of discourse reduces both the distance between the discourse world and the initial world of the language-user (in this case, that of the classroom experiment itself) and between objects and events to be referenced in that discourse world. In terms of the test materials themselves, it seems that grade 6 subjects, having more readily entered the space-fantasy world than other narrative worlds, may have found it easier to locate the information upon which premises were based. This ease of entry into discourse worlds is likely to be the nucleus of an effect which spreads and activates attention and memory. In contrast, refusal or inability to enter a discourse world distances the subject and increases the difficulty of locating, remembering, and thus making deductions about objects, activities, characters, and their interrelations. In this latter case, any related logical task is likely to be approached less directly and more artificially, a situation in which any attempt to synchronize the necessary components of deductive ability is more likely to be defeated by attentional and memorial deficits.

This general interpretation of the interaction between grade 6 and grade 12 performance on the passages must be reconciled, however, with the apparent lack of salience connected with any of the passages for the grade 4 subjects. Observation and evidence of younger children's reasoning suggests that they are responsive to qualitative features of narrative presentation (see Donaldson, 1978, Chapter One, above). It seems likely, then, that the variation included in the present study was insufficiently broad to capture any information about grade 4 preferences. For these subjects, indeed, it is possible that the test situation itself dominated processing, effectively making the narrative discourse worlds equi-distant and relatively difficult to enter.

The claim that narrative effects might be explained in terms of cognitive distances must further be reconciled with the tentative counter-hypothesis mentioned in the previous chapter, namely, that contrast rather than coordination between conditional statement and narrative types might also have had some positive effect on logical performance. The idea that successful entry into a discourse world leads to generalized cognitive facilitiation within that world is associated with the notion that the information domain is relatively coherent. Material which in any way violates the integrity of a discourse world (for example, fantasy reference within a concrete, real-world framework) should demand more cognitive effort. In terms of the tentative model proposed, intrusive reference is interpreted as signaling the presence of a different discourse than the one to which entry has been gained and which constitutes the present cognitive set of the subject. The likely result here is some disorientation and confusion, demanding further effort on the part of the subject to resolve the disparity and, in the case of a study such as this, to resolve it in favour of satisfying the particular processing demands established within the discourse between the subject and the experimenter. The presence of a contrast effect which heightens rather than reduces logical processing is, then, apparently anomalous. It is entirely possible, however, that the observed contrast effect is an artifact of the experimental materials themselves, and that the distinction established between coordinated and uncoordinated materials was simply not well enough defined. Clearly, the anomaly cannot be satisfactorily resolved without further research based upon more precise measures of contrast.

The probability that artifact was responsible for the contradiction with the overall analysis is increased by the presence of several questions which gave rise to atypical responses, responses which affected the measures of significant contrast between the coordinated and uncoordinated materials. One such question was the MT-Inducement type following the Contractual passage. The full syllogistic expression of this problem is

> 10. If you win another fifty dollars on the Joker's Wild, then the first three subjects to appear are "France," "food," and "music,"
>
> The first three subjects are not "France," "food," and "music"
>
> You don't win another fifty dollars on The Joker's Wild.

On further examination of this question in its context, it seems that its unique difficulty for all subjects could have been associated with two features. First, additional complexity may have been involved in matching not one but three items in the premise with the text (France, food, music, vs. animals, Italy and books). While it seems possible to solve the problem by elimination, that is, by recognition of the absence of "animals" in the additional information statement (a concept reinforced in the passage through the descriptions of fondness for reptiles and the answer to the spider question), it seems equally possible that the statement might be processed as three separate concatenated propositions. If this were the case, the characteristics of this MT question clearly combined in a manner which forced disproportionate demands. Second, although both propositions were deliberately written in present tense to accord with the intended immediacy of the contractual passage, the result may have been ambiguous. In particular, the present tense of the consequent proposition seems to force an interpretation for the whole conditional statement in future time, a framework which is in some conflict with the sequence of events in the narrative. The statement would possibly have avoided this temporal ambiguity if it had been expressed in past tense. Both of these additional sources of complexity, moreover, may have been further intensified by the fact that this question came first in the set following the Contractual passage.

These latter interpretations of the particular difficulties connected with the question are further supported by the observation that, taken overall, the

MT/IN questions were solved better than other MT problems. This observation, even more striking if the scores on the question following the Contractual passage are removed from consideration, has some interesting linguistic implications.

In reviewing the linguistic background to research on conditional reasoning, the arguments of Geis and Zwicky (1971) and of Lilje (1972) were presented. One explanation for the generally greater ease with which subjects apparently processed MT/IN problems is consonant with the Conditional Perfection analysis of Geis and Zwicky. If it is the case that promises and threats are habitually "perfected to biconditionals," then, in certain circumstances, this could clearly facilitate the associated logical movement from denial of the consequent to negation of the antecedent which is valid in the solution of Modus Tollens problems. A further reason for the additional complexity of the MT/IN problem following the Contractual passage, then, could be connected with the status of its additional information statement as a promise.

When compared to the other MT/IN statements in the study, the central inducement relation proposed to bond antecedent and consequent propositions in the question seems especially weak. Indeed, the statement, "If you win another fifty dollars on The Joker's Wild, then the first three subjects to appear are 'France,' 'food,' and 'music'" seems more readily interpretable as a statement of the fact of winning an extra fifty dollars, based upon the chance of drawing certain quiz topics, rather than as a description of a reward for a certain behaviour. It is thus possible that one reason for idiosyncratic responses to the question is its failure to satisfy the status of a true Inducement proposition. Since the statement fails to establish the pragmatic bond of fairness or reciprocity normally underlying Inducements, the bond could not be available to subjects. This analysis, consistent both with the general pattern of results found in the study and with the notion of Conditional Perfection proposed by Geis and Zwicky, further emphasizes the semantic complexity of if-then expressions in ordinary language.

Subjects' difficulty with the MP/IN question following the Contractual passage, relative to the other MP questions following the same passage, seems not to have been due to any defect in the additional information statement as a promise. The statement "If you answer the Quebec question correctly, Jack Berry will give you five hundred dollars." apparently satisfies the conditions previously mentioned. The difficulty may well have been associated, however, with the additional complexity involved in combining the two textual ideas - "French is the language spoken in Quebec" and "I answered correctly." Nevertheless, this seems tenuous in the presence of the complexity evident in other matching tasks in the study.

Another possible explanation might be the unique combination of vocative reference and future time in the statement. Resolution of such issues is clearly a matter for further and more detailed research into Inducement expressions.

A final observation concerns the greater ease of logical processing connected with all positive MP-Concrete problems over other positive MP types. Further consideration of the associated additional information statements suggests that the concrete expressions perhaps provided less intrusion into the narrative coherency of uncoordinated passages than did other types. Certainly, the assertion "If Vincent's lights blinked on and off, then the light bulbs got hotter" seems to present a concept which is possibly equally well integrated into the fantasy world of machinery as it would be in the real world. Similarly, the assertion following the Contractual passage "If there are hundreds of television studio lights, then the studio is very warm" does not severely disturb the narrative conventions. Indeed, the similar quality of the concrete reference shared by both these statements, although separated by much intervening test material, may have had some facilitating effect. Both statements seem to provide less narrative intrusion than either the assertion "If the owl is called Lord of the Night, then the duck is called Queen of the Day", initiating the MP-Abstract question following the

Realistic passage, or the Inducement statement following the Fantasy passage, "If Pizer got to the control centre first, he got a reward from the captain." These latter two conditional premises were the ones associated with the two lowest mean scores obtained in the group of MP problems, and this finding seems properly attributable to the violations of narrative coherency which they represent.

In summary, the following central points emerge from consideration of the narrative and conditional statement variation in the study. First, as the Grade x Passage interactions suggest, narrative variation in the study was associated with significant differences in the demonstration and use of deductive logical abilities. In particular, the Fantasy passage appeared to have a variously facilitative or inhibitative effect on subjects. To account for the major observed effects, a cognitive distance model, in which the discourse worlds represented by the narratives stood in some potentially measurable relation to one another was proposed. It was suggested that the significant psychological factors underlying logical performance could be understood in terms of the amounts of effort needed both to access and relinquish these discourse environments. It was argued that the distinctions between grade 4, grade 6, and grade 12 performance was attributable to the different degrees of cognitive proximity involved between subject groups and passages. It was emphasized that further refinement of terminology, together with development of clearer distinction between coordinated and uncoordinated materials and elimination of artifact, would be needed before a more detailed model could be proposed.

Second, analysis of the semantic characteristics of particular conditional premises used in the study revealed the presence of many features possibly influencing subjects' performance. While further indicating the complexity of conditional expressions, these observations did not invalidate the tentative cognitive model proposed. Variations in dependent measures connected with individual questions and not predicted in the experimental hypotheses seem, rather, to have been due to various infractions of experimental intent. Propositional complexity, repetition of ideas, and insufficient contrast between statements and their narrative context were all found to have had possible influence. However, when matters of extraneous variation were accounted for, in particular, those associated with Inducements, the data seemed consistent with the original hypotheses.

Conclusions

Variation in the interpretability of conditional premises seems to relate not only, as has been adequately demonstrated in earlier studies, to their internal linguistic content or performative framework, but also to the qualities of the discourse worlds serving as the larger contexts for these features themselves. While internal structural and semantic features of conditional statements, for example, negation, have important effects on processing, it seems reasonable to propose from the observations made in the present study that these statements may have the further function of serving as "keys" of entry and exit to and from such discourse worlds, rather than simply as initiators of logical algorithms. In this way, part of the semantic content of conditional statements can be understood as some sort of signaling reference to the world in which they are to be most appropriately interpreted. They are in a sense invitations to the language-user to construct the proper environments for problem solution as well as to solve deductive problems themselves.

This property of semantic duality held by if-then statements carries with it some important implications for logical testing procedures involving such statements for, as the results following systematic narrative variation demonstrate, responses to conditional invitations vary as a function of the environments signaled. What may have happened in earlier testing procedures leading to various structuralist assessments of age-related logical abilities was that conditional statements initiating tasks (in various modes of presentation) may have been understood by subjects as invitations to enter a world in which they had neither experience nor interest, namely, the discourse world of experimental testing itself. In distinguishing between this latter world and the locations of everyday processing, it seems reasonable to propose that the particular setting associated with traditional logical testing procedures may be unique in its neutralization of the semantic duality normally associated with if-then statements. It is only in this form of discourse (used in extension from the academic discourse of formal logic itself), in other words, that the semantic richness of if-then statements is reduced to the point where they are intended to function solely as initiators of syllogistic problems, a reduction causing potential interpretive confusion.

This effective reduction in the amount of information normally contained in conditional statements may to some extent underlie both the findings of support for structuralist accounts of age-related logical limitations and the evident lack of correspondence between observed deductive reasoning and the form of the propositional calculus itself previously noted. While it seems likely that no experimental procedure can totally avoid some such sort of reduction, the results of this study indicate that narrative variation could provide a method of presentation in which the semantic integrity of conditional statements is maintained. This idea both complements and extends the view of narrative "microcosm" proposed by Bower (1978), that of the "chameleon-like nature" of conditional statements suggested by Wason and Johnson-Laird (1972), and may to some extent indicate the possible ways in which a processing model such as that of Braine (1978) might be further developed by refining the notion of "grammatical frame" in terms of discourse world context.

One other indication of the potential importance of attending to discourse variation in studies of logical reasoning may be found in the long-standing popularity of certain children's fantasy narratives containing far greater logical complexity and variation than that contained in the present study. Foremost among such narratives are those by Lewis Caroll. It is interesting to note, however, that, as a recent study of Carroll's attempts to make formal logic amenable to young children indicates, when he cast complex problems in other frames, as he did in _The game of logic_, he was apparently far less successful in his enterprise than he had been in the stories _Through the looking glass_ and _Alice's adventures in Wonderland_ (see Fisher, 1975, pp. 163-181; Carroll, 1958; Green, 1965).

In returning to consider once more the problem of interpretation of the terms _abstract_ and _concrete_ in tests of logical abilities, it can be seen both from young children's responses to abstract fantasies such as those of Lewis Carroll and from the observations in the present study that the distinction between them is not as simple as has often been proposed and, in any case, cannot rest solely upon the status of lexical items as referrents in the real world. What is an abstract sentence or premise in one discourse world may stand in a very different relation within another such world and, while much further study and refinement is needed of the notion of cognitive distance between discourse worlds, it seems that the distinction between abstract and concrete content must ultimately be related to the internal dynamics of discourse world processing. In this way, abstract and concrete expressions may be defined as functions of particular discourses rather than as absolute properties of the lexicon. This revaluation of the distinctions further implies a reassessment of the justification for distinguishing, in Piaget's terms, between formal-operational and concrete-operational behaviour, an opposition founded on a distinction between abstract and concrete processing as it relates only to real world reference. The assertion of cognitive stages in logical processing, then, if it is maintained at all, seems to be more aptly predicated on the notion of experience in cognitive shifting between discourse worlds than upon either the internal content or form of logical arguments themselves.

The notion of distances between possible worlds has already received some attention in the context of modal logic, most notably in the the work of Lewis (1968, 1973), who introduced the concept of degrees of similarity into his treatment of counterfactuals. While they are well beyond the scope of the present study, the definitional problems connected with "transworld identity" and, more generally, the related distinctions between *extensional* and *intensional* predicates, well reviewed, for example, by Allwood, Andersson, and Dahl, (1977, pp. 125-130), are all important for further refinement of the central matters considered here.

The problems of definition connected with *psychologism* are essentially the same ones underlying the assessment of logical abilities. In a recent survey of the area, Haack (1978) has outlined three possible positions concerning the relations between logic and thought:

> 1. *strong psychologism* - "logic is descriptive of mental processes,"
> 2. *weak psychologism* - "logic is prescriptive of mental processes,"
> 3. *anti-psychologism* - "logic has nothing to do with mental processes."
>
> (p. 238)

It will be recalled that the structuralist position of Inhelder and Piaget (1958) embraced the first of these approaches. The last position was essentially that of Frege in his critique of Boole (see Henle, 1962, in Chapter Two, above). In supporting the second of the positions (weak psychologism), Haack herself argues as follows:

> Logic...is prescriptive of reasoning in the limited sense that inference in accordance with logical principles is safe...
> It is important, however, that on the weak psychologistic view, though logic is applicable to reasoning, the validity of an argument consists in its truth-preserving character; it is in no sense a psychological property. Consequently, weak psychologism avoids the main difficulty of strong psychologism, the problem of accounting for error; for, since people surely do, from time to time, argue invalidly, how could the validity of an argument consist in its conformity to the way we think?
> (p. 241)

While lending general support to the position of weak psychologism as presented by Haack, it seems possible from the results of the present study to go beyond the argument based on logical fallibility to suggest that the problem of psychologism may also lie in the insistence upon associating logical behaviour with the wrong sets of psychological primitives. In the light of this research into narrative variables, it seems appropriate, for example, to relate some of the central aspects of logical behaviour to well-established psychological phenomena, such as the propensity for figure-ground perception, before attempting any more detailed modeling of logical processing sequences per se.

The importance of perceptual frames in the comprehension and solution of a wide range of reasoning problems by young children has been emphasized in studies by Bryant (1974) and by Bower (1974), and it is this variety of observation which seems to have more general significance for the modeling of reasoning in context than the more traditional attempts to explain by way of translating logical calculi in isolation from these wider processes. In other words, by incorporating hypotheses derived from a much wider psychological domain than has previously been typical, it may be possible to view the problem of psychologism not fundamentally as one of the inappropriacy of comparing natural reasoning to formal logic. As the present research has once again demonstrated, there seems to be considerable propensity to behave in accordance with the propositional calculus but, as it also demonstrates, such accordance follows significant contextual cueing and seems to be associated with complex cognitive shifts of various kinds. From the point of view of modeling behaviour, the criteria of "logical validity" and "error" which underlie the various versions of psychologism may simply be inappropriate. As previously suggested, they are part of a discourse which forms a base too restricted for the analysis of logico-linguistic behaviour.

Another way of viewing this matter is to regard logical forms as described by the theorist as constituting rules of a different kind from those incorporated into everyday usage, different not so much in their basic form as in how they are followed. Rule-following in these two cases will be connected with distinct levels of knowledge and of conscious processing, a distinction brought out in a number of related discussions concerning the more general relations between the constructions of grammarians and the less conscious character of actual language use (see, e.g., Cooper, 1974, pp. 39-84).

Limitations of the Study

Although the analysis of the data supports the interpretations and conclusions offered, both are to be understood in the light of the various limitations which have been noted. These may be summarized as follows.

First, the testing procedures adopted produced too high a proportion of rejected data. In seeking to explore the effects of a number of variables at once, the test itself apparently became too lengthy and complex for a large number of younger subjects.

Second, while an interesting Sex x Grade interaction was noticed, insufficient background information about subjects was gathered to develop an explanation. In particular, the interpretation of the underlying causes of such an effect might rest either upon variation in the materials or in age-related classroom behaviour.

Third, while the metacognitive measures were of potential importance for establishing the role of knowledge in the sensitivity of subject groups to the various discourse worlds presented, they failed to provide such information. Determining the extent of metacognitive involvement in reasoning tasks is clearly an empirical issue of central importance for the further understanding of logico-linguistic development. The complexity of the potential interactions between such involvement and contextual or linguistic variations was underestimated in the present study. In particular, insufficient care was taken to ensure that the metacognitive performance of subjects' was not confounded with simple knowledge or ignorance of lexical items used in the test. More generally, it seems unwise to make the assumption either that the logical processing of even the most sophisticated adult language user is affected by his knowledge of contextual or narrative characteristics or, indeed, that metacognitive involvement is necessarily associated with cognitive facilitation rather than additional complexity.

Fourth, certain noted artifacts may have resulted from characteristics of particular conditional statements in the materials. Such artifacts led to a reduction in the clarity of definition of the linguistic categories proposed.

While these limitations have been allowed for in the interpretation of this study, attention to these problems in future research will permit greater precision and reliability.

Suggestions for Further Research

The study might be valuably extended in a number of ways. In relation to the limitations acknowledged (see

Limitations, above), first, modification of the testing procedures to suit the attentional capacities of younger subjects should produce interesting results. In particular, individualized oral presentation over several testing sessions, while an inevitably more lengthy procedure, might yield more detailed information about younger children's narrative preferences. Second, disambiguation of the interesting Sex x Grade interaction found in this study demands further variation of materials in terms of their specific appeal to subjects of either sex. Third, better design of metacognitive questions should lead to observations of the role of subjective awareness in logical discourse processing. Such an improvement is essential for refinement of the notion of cognitive distance between discourse worlds.

Further valuable information might also come from the inclusion of pure hypothetical syllogisms, quantificational syllogisms, the Fallacies, and of counterfactual and other conditional statement types. Apart from the potential importance of such research for understanding the development of reasoning, it seems that studies might also be directed towards finding the discourse frames which provide the most suitable contexts for the teaching and learning of concepts involving logical connectives. According to the findings of the present study, the nature of these frames will vary with age, while the quality of logical processing, insofar as it can be isolated from linguistic abilities in general, will remain relatively stable and unchanged across the age range in question.

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APPENDIX A

Basic argument forms of the propositional calculus

Modus Ponens

$$\begin{array}{l} p \supset q \\ \underline{p \quad\quad} \\ q \end{array}$$

Modus Tollens

$$\begin{array}{l} p \supset q \\ \sim\underline{q \quad\quad} \\ \sim p \end{array}$$

Fallacy
of
Affirming the Consequent

$$\begin{array}{l} p \supset q \\ \underline{q \quad\quad} \\ p \end{array}$$

Fallacy
of
Denying the Antecedent

$$\begin{array}{l} p \supset q \\ \sim\underline{p \quad\quad} \\ \sim q \end{array}$$

Truth-tables referred to in the text

a. Material Implication:

p	q	$p \supset q$
T	T	T
T	F	F
F	T	T
F	F	T

b. Material Equivalence (Biconditionality):

p	q	$p \equiv q$
T	T	T
T	F	F
F	T	F
F	F	T

c. The "defective truth-table" of Wason and Johnson-Laird:

p	q	$p \supset q$
T	T	T
T	F	F
F	T	Void
F	F	Void

(1972, p.90)

Categorical statement types:

Examples of the four kinds of categorical proposition taken from Copi, 1978, p.166.

A: All politicians are liars

E: No politicians are liars

I: Some politicians are liars

O: Some politicians are not liars

A syllogisms's mood is determined by the particular combination of A, E, I, O propositions it contains. Listing all of the possible AAA, AAE, AAI, AAO, AEA... combinations yields 64 types.

APPENDIX B

This appendix contains a description of the test materials. The exemplary passage and questions, which were the same for all subjects (except that they were printed in Primary Script, as were all other materials, for grade 4 subjects), are presented first, followed by each of the three texts in each of their three grade level versions. The Dale-Chall readability score is given for each of the nine texts used. Finally, a briefer account is given of the additional information statements and test questions themselves in terms of the grade 6 materials. (The language of statements and questions varied slightly from grade to grade in coordination with particular text versions presented).

a. Example material

Joe and Farah live in an apartment in Vancouver. Joe likes soup and so Farah is making some in the kitchen. Farah's mother and her two cats also live in the apartment, but her mother does not like soup. She is watching Mork and Mindy on television.

1. Extra information:

If Joe lives in an apartment, he often uses the elevator.

Which is true? Give the BEST answer, USING BOTH THE PASSAGE AND THE EXTRA INFORMATION. Circle ONE.

a. Joe and Farah live on the 16th floor.

b. Farah's mother has two cats.

c. Joe does not live in an apartment.

d. Joe often uses the elevator.

e. Can't tell.

WHY is your choice the best one? (Because he lives in an apartment)

2. If the apartment window is closed, Farah's mother likes soup.

Which is true? Circle the BEST answer only.

a. Farah's mother likes soup.

b. The window is not closed.

c. The window is made of glass.

d. Farah's mother is watching TV.

e. Can't tell.

WHY? (Because Farah's mother does not like soup).

3. If Joe owns a dog, then the dog's name is Henry

Which is true?

a. Joe rides a bicycle.

b. Joe doesn't own a dog.

c. The dog is black and white.

d. The dog's name is Henry.

e. Can't tell.

Why? (Insufficient information).

4. If Farah's mother does not like soup, then she does not drive a car

Which is true?

a. Farah's mother likes soup.

b. Farah's mother's car is not a Pontiac.

c. Farah's mother does not drive a car.

d. Farah's mother is not watching The Muppets.

e. Can't tell.

Why? (Because Farah's mother does not like soup).

b. The nine texts

1. Grade 4 Fantasy Passage (Dale-Chall: 4.9)

The deep space search rocket, Palomino, had been looking for alien life in a far-away part of the universe. The men on board had found nothing but a few small plants. Nothing very interesting had taken place. On December 24th. in the year 2006, however, all that changed suddenly. The Palomino's crew were awakened by the electronic voice of the robot, Vincent. It came from the control room. "I am sorry for waking you all. There is something I think you should see. I've put it on the central screen." Pizer, the First Officer, was the first to reach the control room. Vincent's many arms were neatly folded back against his hovering barrel-shaped body. On the top of his metal head, his blue indicator light flashed continuously. Other lights also blinked on and off as his inside motors directed. Vincent said nothing as Pizer entered. In the upper right quarter of the central monitor screen was a dark egg-shaped form. It was circled by tightly bunched lines like those on a map. These lines showed signs of powerful gravitation. Vincent made the picture bigger. The lines should have moved further apart as the picture got bigger, but they stayed as close together as before. The Palomino's computers measured the power of the gravitation at the centre of the dark shape. Pizer let out a low whistle when the numbers appeared. "That is the most powerful black hole I have ever come across", said Vincent. "I do not remember anything stronger. I think the hole must contain the remains of something between forty and a hundred large stars."

2. Grade 6 Fantasy Passage (Dale-Chall: 5.8)

The deep space research vehicle, Palomino, had been searching for alien life in a distant section of the galaxy. The scientists on board had found nothing but a few small plants, and nothing else very interesting had taken place. On December 24th., 2006, however, all that changed when the crew were interrupted by the electronic voice of the robot, Vincent, coming from the control room, "I am sorry for the interruption, but there is something I think you all should see. I've put it on the central viewer." First to reach the control centre was Pizer, the First Officer. Vincent's many arms were folded neatly back against his hovering barrel-shaped body. On the top of his metal head, his blue indicator light flashed continuously. Other indicator lights also blinked on and off as his internal motors directed. Vincent said nothing as Pizer entered. In the upper right quarter of the central monitor screen was a dark egg-shaped form circled by tightly bunched lines like those on a map. These lines represented regions of powerful gravitation. Vincent made the picture bigger, but instead of moving further apart as the picture got bigger, the lines around the dark form remained as close together as before. The Palomino's computers measured the power of the gravitation at the centre of the dark shape. Pizer let out a low whistle when the figures appeared. "That is the most powerful black hole I have ever come across", said Vincent. "My memory banks hold no trace of anything stronger. I think the hole must contain the remains of anywhere from forty to a hundred large stars."

3. Grade 12 Fantasy Passage (Dale-Chall: 8.3)

The deep space research vessel, Palomino, had been searching for alien life in a remote sector of the galaxy. The scientists on board had found nothing but a few unimportant microbes and little else of interest had occurred. On December 24th., 2006, however, this passivity was reversed when the crew were interrupted by the electronic voice of Vincent, Palomino's robot, coming from the command console. "I apologize for the intrusion, but there is something I think you all should see. I've put it on the Nikko-Scan viewer." First to reach the command centre was Pizer, the First Officer. Vincent's multiple extensions were folded neatly back against his hovering barrel-shaped body. On the top of his platinum dome, his blue mode indicator light flashed continuously, and other lights also blinked on and off according to his internal function states. Vincent uttered nothing as Pizer entered. In the upper right quadrant of the Nikko-Scan a dark oval blotch could be seen, encircled by tightly bunched lines like those on a topological map. The lines represented regions of powerful gravitational force. Vincent magnified the image, but the lines around the blotch remained as close together as before. The Palomino's Series 15 IBM measured the gravitational force centred in the oval void. Pizer let out a low whistle when the print-out figures emerged. "That is the most powerful black hole I have encountered," croaked Vincent. "My banks hold no memory trace of anything stronger. I estimate the hole contains the remnants of between forty and a hundred stellar masses."

4. Grade 4 Reality Passage (Dale-Chall: 4.5)

There is no animal that can see in complete darkness. But the owl is called "Lord of the Night" because he can see to hunt when there is very little light. One kind of owl which is very often seen in Canada is the barn-owl. The barn-owl can see one hundred times better than we can. He can catch mice when the light is even weaker than the light made by a single candle half a mile away. This light is so dim that men could see nothing with it. A barn-owl's eye is much larger than a man's eye. His eyes do not move in the same way as ours do. Each eye is fixed like the headlights on a car. To see in different directions, the owl turns his whole head around. The barn-owl also has good hearing. His ears are well-shaped for the greatest hearing power. His face has stiff curved feathers that direct sounds into his ears. In some owls, the ear openings cover both sides of the head. The barn-owl knows exactly where a sound comes from even in the dark. Because the barn-owl does not have a small head, his ears are far apart. Sounds reach one ear before the other and this helps him tell the direction they come from. The barn-owl's good sight and hearing make him a good hunter. Because he is so good at hunting, he is valuable to the farmer. He does not eat fruit and feeds mostly on mice, rabbits and moles, which can destroy crops and forests. He also catches animals larger than himself, such as porcupines and turkeys. He never attacks farm animals, though.

5. Grade 6 Reality Passage (Dale-Chall: 5.2)

There is no animal that can see in complete darkness. But the owl is called "Lord of the Night" because he can see to hunt when there is very little light. One kind of owl which is very common in Canada is the barn-owl. The barn-owl can see one hundred times better than humans can. He can catch mice when the light is even weaker than the light made by a single candle half a mile away, a light so dim that men could see nothing with it. A barn-owl's eye is much larger than a human eye. His eyes do not move in the same manner as ours do. Each eye is fixed like the headlights on a car. To see in different directions, the barn-owl swivels his whole head around. The barn-owl also has excellent hearing. His ears are specially shaped for the greatest hearing power. His face has stiff curved feathers that direct sounds into his eardrums and, in some owls, the ear openings cover both sides of the head. They know exactly where a sound originates from, even in the dark. Because the barn-owl does not have a small head, his ears are far apart. Sounds reach one ear before the other and this helps him tell the direction they come from. The barn-owl's good sight and hearing make him a good hunter and, because he is so good at hunting, he is valuable to the farmer. He does not eat fruit, and feeds mostly on rodents (mice, rabbits and moles), which can destroy crops and forests. The barn-owl also catches animals larger than himself, such as porcupines and turkeys. He never attacks farm animals, though.

6. Grade 12 Reality Passage (Dale-Chall: 8.3)

No creature is capable of sight in absolute darkness. However, the owl is described as "Lord of the Night" in recognition of his capacity for nocturnal hunting in the near absence of illumination. Barn-owls, often visible in Canada, can see a hundred times better than can humans and some prey on rodents under light no more powerful than that radiating from a candle placed at a distance of half a mile - a light too faint for humans to see anything. The barn-owl's optical equipment is larger than the human's and does not move in a similar manner, as each eye is fixed like an automobile's headlights. For the owl to see in different directions, it is necessary for it to swivel its entire head around. Barn-owls have excellent hearing and their ears are specially disigned for optimum auditory power. The barn-owl's face is surrounded by stiff curved feathers which focus sound-waves on the eardrum and, in some owls, the ear apertures entirely cover both sides of the head. They know the exact origins of sounds even in the dark. Because the barn-owl's head is not small, the ears are distanced from each other and, hence, sounds reach one ear before the other, aiding its directional perception. The barn-owl's excellent visual and auditory capabilities make it a fine hunter, a characteristic of considerable value to the farmer, as it is not a vegetarian and feeds mostly on rodents which would otherwise be potentially destructive to crops and forests. Barn-owls often catch prey of larger dimensions than themselves, such as porcupines and turkeys, although they never attack farm animals.

7. Grade 4 Contractual Passage (Dale-Chall: 4.7)

After trying for many months, you have been able to get on the television quiz show, The Joker's Wild. You are a little scared under the glare of hundreds of television studio lights. The person you have to play against is a policeman from San Francisco. He has so far got all the questions right and has won four thousand dollars. The people watching the show in the studio are still shouting and clapping as you arrive. You stand to the right of the policeman and shake his hand. He does not smile. Jach

Berry, the game show host, introduces you to everyone watching. He tells them that you do not come from the Unitied States. You come from British Columbia and like talking to your pet frogs. You start the game off by pulling a lever. You do not pull it hard enough and have to try again. The first three subjects that appear are "animals", "Italy" and "books." You know a lot about animals and so you choose this. Jack Berry asks you, "How many legs does a spider have?" You answer, "twelve." This is wrong and so the question goes to the policeman. He does not get the answer right either. He answers, "seven." Neither of you has won any money in this game so far. The second time you pull the lever, you are luckier. Three jokers appear. The people shout and clap again and the policeman looks worried. You can choose the subject you like best and which you know most about. You choose "c Canada" and Jack Berry asks you, "What is the language spoken in Quebec - Spanish, French, or German?" You give the correct answer, of course.

8. Grade 6 Contractual Passage (Dale-Chall: 5.1)

After many months of trying, you have been able to get a place as a competitor on the television quia show, The Joker's Wild. You are a little nervous under the glare of hundreds of television studio lights. The person you have to play against is a policeman from San Francisco. He has so far got all the questions right and has won four thousand dollars. The people watching the show in the studio audience are still shouting and clapping as you arrive. You stand to the right of the policeman and shake his hand, byt he does not smile. Jack Berry, the game show host, introduces you to everyone watching. He announces to them that you do not come from the United States. You come from British Columbia and like talking to your pet frogs. You start the game off by pulling a lever. You do not pull it hard enough and have to try again. The first three subjects that appear are "animals," "Italy," and "books." You know a lot about animals and so you choose this. Jack Berry inquires: "How many legs does a spider have?" You answer, "twelve." This is wrong and so the question goes to the policeman. He does not answer the question successfully either as he answers "seven." Neither of you has won any money so far in this game. The second time you pull the lever, you are luckier because three jokers appear. The people shout and clap again and the policeman looks anxious. You can select the subject you like best and which you know most about. You choose "Canada" and Jack Berry asks you: "What is the language spoken in Quebec - Spanish, French, or German?" You give the correct answer, of course.

9. Grade 12 Contractual Passage (Dale-Chall: 8.6)

Many months of frustration have ended when you finally secure a place on the TV quiz show, The Joker's Wild. You are somewhat nervous under the glare of hundreds of studio lights, [illegible] feeling intensified by the fact that your opponent is a San Francisco policeman who has so far successfully answered every question and has won four thousand dollars. The studio audience continues to applaud as you arrive to stand at the right of the policeman, whose hand you shake, despite his apparently unchanging solemn mood. Jack Berry, the game show host, introduces you to the fascinated audience, announcing to them that your origins are not in the United States, that you are an inhabitant of British Columbia, and that you have a fondness for engaging in conversation with your pet reptiles. You initiate the proceedings by tugging on a lever, but unfortunately fail at the first attempt to pull vigorously enough and so have to repeat the process. The first three topics to emerge are "animal physiology," "Italian painters," and "great literature." Your superior knowledge of reptilian behaviour persuades you to choose the first topic, and Jack Berry inquires: "How many legs has a spider?" He is somewhat taken aback when your considered response is "twelve." Your ignorance gives the policeman a chance, but he is equally ignorant, answering "seven." Neither of you has any winnings so far, but your second turn brings more luck as three jokers appear, making the audience excited once again and perturbing the policeman. Now you can select any topic you feel best suits your abilities. You choose "Canada" and Jack Berry asks you: "Which of the following languages is the dominant language of Quebec - Spanish, French, or Russian?" You naturally give a faultless reply.

c. The test questions

As described in Chapter Three, the multiple-choice question sets followed a systematic pattern of variation. Questions all followed the general pattern of presentation given in the Example section (see above). Below are listed the actual syllogisms at the basis of the testing. The first premise is the additional information statement (as presented in the Grade 6 materials), the conclusion is the correct choice from the given multiple-choice set, and the second premise is the enthymematic insertion based upon the textual information and following the question "why is it true?" In the case of the Recognition questions, the additional information statement is followed by the correct multiple-choice selection and justification. The order given is that of the actual test presentation, and the description of argument types follows the abbreviations to be found in Table 1.

Fantasy Passage

F1. MT/IN

If Pizer gave Vincent his favorite oil, then Vincent said "good afternoon Sir" as Pizer entered the control centre

Vincent did not say "good afternoon"...

Pizer did not give Vincent his favorite oil.

F2. MP/AB

If Vincent's blue indicator light was flashing, then an orange light also appeared on his left shoulder

Vincent's blue indicator light was flashing

An orange light appeared on his left shoulder.

F3. RE/NE

If Vincent was not silver-coloured, the control centre was not warm

Can't tell

Insufficient information.

F4. MP/NE

If the lines around the dark form did not get further apart, then the computer screen did not show a yellow diamond

The lines around the dark form did not get further apart

The computer screen did not show a yellow diamond.

F5. MT/CO

If the computer showed only a small number, then the black hole's gravitational power was weak

The black hole's gravitational power was not weak

The computer did not show a small number.

F6. MP/CO

If some of Vincent's lights blinked on and off, then the light bulbs got hotter

Some of Vincent's lights blinked on and off

The light bulbs got hotter.

F7. RE/PO

If the Palomino had started out from the United States, then it had ten main engines

Can't tell

Insufficient information.

F8. MP/IN

If Pizer got to the control centre first, he got a reward from the captain

Pizer got to the control centre first

Pizer got a reward from the captain.

F9. MT/AB

If Vincent's metal head turned around, then he remembered something stronger than the black hole.

Vincent did not remember anything stronger than the black hole

Vincent's metal head did not turn around.

Realistic Passage

R1. MP/CO

If the barn-owl's eyes are fixed like a car's headlights, then he can only see in the direction his head points

The barn-owl's eyes are fixed like a car's headlights

The barn-owl can only see in the direction his head points.

R2. MT/AB

If the farmer wears large boots, then the barn-owl has a small head

The barn-owl does not have a small head

The farmer does not wear large boots.

R3. MP/IN

If the barn-owl catches mice, then the farmer will let him stay in the barns

The barn-owl catches mice

The farmer will let the barn-owl stay in the barns.

R4. RE/PO

If the barn-owl often sits on fences, the farmer shouts at him

Can't tell

Insufficient information.

R5. MT/IN

If the farmer shoots at the barn-owl, the owl attacks farm animals

The barn-owl does not attack farm animals

The farmer does not shoot at the barn-owl.

R6. MT/CO

If the mole can see underground, then some animals can see in complete darkness

No animals can see in complete darkness

The mole cannot see underground.

R7. MP/AB

If the owl is called "Lord of the Night", then the duck is called "Queen of the Day"

The owl is called "Lord of the Night"

The duck is called "Queen of the Day."

R8. RE/NE

If the farmer's wife is not angry at the barn-owl, the owl has not been hooting all night

Can't tell

Insufficient information

R9. MP/NE

If the barn-owl does not eat fruit, he does not eat much sweet food

The barn-owl does not eat fruit

The barn-owl does not eat much sweet food.

Contractual Passage

C1. MT/IN

If you win another fifty dollars on The Joker's Wild, then the first three subjects to appear are "France," "food," and "music"

The first three subjects are not "France," "food," and "music"

You don't win another fifty dollars on The Joker's Wild.

C2. MP/IN

If you answer the question about Quebec correctly, Jack Berry will give you five hundred dollars

You answer the Quebec question correctly

Jack Berry will give you five hundred dollars.

C3. MT/CO

If the wheels showing the subjects spin fast, then you pull the lever very hard the first time

You don't pull the lever hard the first time

The wheels showing the subjects do not spin fast.

C4. RE/PO

If the next person you play on The Joker's Wild is a woman, then the next question you answer is about "television"

Can't tell

Insufficient information.

C5. MP/NE

If you do not answer the question about the spider correctly, Jack Berry will not give you a bonus prize

You do not answer the question about the spider correctly

Jack Berry will not give you a bonus prize.

C6. MP/CO

If there are hundreds of television studio lights, then the studio is very warm

There are hundreds of television studio lights

The studio is very warm.

C7. MT/AB

If there is a green light directly in front of you, then you stand to the left of the policeman

You do not stand to the left of the policeman

There is not a green light directly in front of you.

C8. MP/AB

If the person you play against is a policeman, then Jack Berry is wearing a brown suit

You play against a policeman

Jack Berry is wearing a brown suit.

C9. RE/NE

If Jack Berry is not wearing a blue shirt, then the policeman does not have gray hair

Can't tell

Insufficient information.

Question 10 (following each passage)

Which of these describes the passage best? Circle one.

a. It actually happened.

b. It's realistic.

c. It's possible.

d. It's not possible

e. It's just imagined.

The final question (following presentation of all materials)

What do you think all the questions you answered show best? Circle one.

a. How well you can read and write English.

b. How well you can count.

c. How well you understand the passages.

d. How well you can think and reason.

APPENDIX C

This appendix contains some examples of grade 6 subjects' responses to questions 6, 7, and 8, following the Realistic passage. In each case, answer A is that of a female subject aged 11 years, 10 months. Answer B is that of a male subject aged 12 years, 4 months, and answer C, that of a female subject aged 11 years, 11 months. Following each answer, any associated syllogistic form is mentioned, together with the response category assigned (see Tables 2 and 3). Symbols associate each written answer with its related multiple choice selection.

6. If the mole can see underground, then some animals can see in complete darkness.

Which is true?

a. There are animals that can see in complete darkness.

b. The mole has a good sense of smell.

‡c. The mole cannot see underground.

+d. The mole is hunted by the owl.

✗e. Can't tell.

Why?

A. ✗ Does not tell. (- : UD)

B. + It said in the story. (- : JE)

C. ‡ Because dirt would get in their eyes. (MT: EL)

7. If the owl is called "lord of the night," then the duck is called "queen of the day."

Which is true?

a. The barn-owl is often seen in Canada.

b. The owl is not called "lord of the night."

X+c. The duck is called "queen of the day."

d. The swan is called "prince of the morning."

‡e. Can't tell.

Why?

A. X Because the owl is called lord of the night. (MP+: CL)

B. + Because the owl is lord of the night. (MP+: CL)

C. ‡ Because it doesn't say. (- : UD)

8. If the farmer's wife is not angry at the barn-owl, the owl has not been hooting all night.

Which is true?

a. The farmer's wife does not like foxes.

b. The barn-owl does not sit in the oak tree.

Xc. The farmer's wife is angry at the barn-owl.

‡+d. The owl has not been hooting all night.

e. Can't tell.

Why?

A. X Because he hoots all night. (MT-: TL)

B. + Because the farmer's wife is not angry. (MP-: TL)

C. ‡ Because the farmer's wife is not mad. (MP-: TL)